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**IMPROVED NEUTRON ACTIVATION  
PREDICTION CODE SYSTEM  
DEVELOPMENT — FINAL REPORT**

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*Prepared by*

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<p>16. Abstract Two Integrated Neutron Activation Prediction (INAP) Code Systems have been developed by modifying and integrating existing computer programs to perform the necessary computations to determine neutron induced activation gamma ray doses and dose rates in complex geometries. All component programs are in FORTRAN IV for the UNIVAC 1108 (Ex 8 System). Each of the two INAP Systems is comprised of three computational modules. The first program module computes the spatial and energy distribution of the neutron flux from an input source and prepares input data for the second program which performs the reaction rate, decay chain and activation gamma source calculations. A third module then accepts input prepared by the second program to compute the cumulative gamma doses and/or dose rates at specified detector locations in complex, three-dimensional geometries.</p> <p>An "Engineering System" which may be used for preliminary design was developed by modifying and integrating the DOT two-dimensional, discrete ordinates program; the NAP neutron activation prediction program; and the KAPV point kernel integration program. An "Accurate System" which may be used for final design evaluation was developed by modifying and integrating the FASTER Monte Carlo transport program for use as both the neutron transport and gamma ray shielding modules with the NAP program performing the activation and decay chain calculations.</p> <p>The internal logic and algorithms of the programs integrated into the two systems are essentially unchanged from the versions currently available from the Radiation Shielding Information Center, however, the input and output routines have been modified and, in some cases, specialized to facilitate the calculation of the doses and dose rates from activation gamma rays in complex structures.</p> <p>The neutron source may be volume distributed or an incident angular flux. Both the cumulative dose and/or dose rate may be determined at specified detector locations. Both the Accurate and Engineering Systems treat the neutron and gamma ray transport as time independent. The time dependence of the dose rate is determined by the NAP program through the power history of the neutron source and the decay rates of the radioactive parents and daughters in the various decay chains produced by neutron activation.</p>					
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## FOREWORD

Programs for the development of radiation hardened materials and components for use on the nuclear flight stage which utilizes one of the (NERVA) engine prototypes currently under development require accurate calculation of the radiation environments at any point throughout the stage.

With the frequent conceptual changes in the design of the nuclear vehicle, these calculations must be rerun periodically with new geometries and parameters. The total radiation environment associated with the operation of a NERVA engine can be considered as arising from the primary radiation produced by the reactor during the burn, and secondary radiation emitted by materials and components that have been activated by the neutron flux produced during the burn and cooldown cycles.

Computer codes have been developed that satisfactorily perform the computation of the primary radiation environments produced during the burn and cooldown cycles of the NERVA engine; however, the codes that are currently available to compute the secondary radiation environments are limited in their usefulness and require improvement.

It is the objective of this effort under Contract #NAS8-25586 from Marshall Space Flight Center to develop improved code systems utilizing only currently proven, operational computer codes with a minimum of internal code modification. The INAP (Integrated Neutron Activation Prediction) Code Systems are capable of determining the secondary radiation levels which result from neutron activation of materials and components associated with the nuclear stage and/or hot firing test stand.

This report represents a programmers and users manual for two code systems. One is an Accurate System for final design calculations and the other is an Engineering System for survey and preliminary design calculations.

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## 1.0 INTRODUCTION

Radiation environments throughout the nuclear flight stage which utilizes one of the (NERVA) engines may be significantly increased by the secondary radiation emitted by materials and components that have been activated by the neutron flux produced during the engine burn and cooldown cycles. The magnitude of the secondary radiation environment may be greatly enhanced or reduced by the selection of materials to be utilized in and around the nuclear stage, therefore, it is necessary to have a tool with which such environments may be determined and parametric studies performed to select materials which will minimize secondary radiations.

It is the objective of this effort under Contract #NAS8-25586 from Marshall Space Flight Center to develop an improved neutron activation prediction code system utilizing only currently, proven, operational computer programs with a minimum of internal code modification. The INAP (Integrated Neutron Activation Prediction) Code System must be capable of determining the secondary radiation levels which result from neutron activation of materials and components associated with the nuclear stage and/or hot firing test stand.

In the Phase A effort, all codes which were described in the open literature of nuclear science and its applications were reviewed and over sixty programs which potentially could be used in the INAP systems were identified. The available documentation for these computer programs was obtained and each code was evaluated to determine its usefulness in the Code System. From this second evaluation ten programs were selected and seven different code systems utilizing these codes were proposed and investigated.<sup>(1)</sup> As a result of this investigation it was recommended that two individual code systems be developed: one a flexible Engineering System intended for engineering estimates and parametric studies that is capable of providing reliable estimates with a relatively small investment in machine time; the other an Accurate System intended for final design and test analyses. Further it was recommended that the Engineering System be developed by integrating the DØT, NAP, and KAPV computer programs and the accurate system should consist of the FASTER and NAP programs.

This report is intended as a programmers and users manual for the two code systems. However, since the programs have only been modified and since there already is considerable documentation for each of these programs (see references 2-9) this report will deal with those areas of the programs where changes were made as well as give descriptions of the input and output of each program and describe how the programs are used within the two systems.

Sections 2.0 and 3.0 represent the manuals for use of the Engineering System and Accurate System, respectively. Within each section, the input and output description of each of the component programs are given first. Then instructions for the operation of that code system are presented and, finally, a sample problem for exercising the system is described.

## 2.0 ENGINEERING SYSTEM

### 2.1 Introduction

The objective of an engineering neutron activation prediction code system is to economically and efficiently perform the activation and shielding analysis with sufficient accuracy to satisfy most engineering requirements. For such a system it is, of course, necessary to sacrifice somewhat the precision of the numerical approximation to the transport problem and/or the capability to model complex material structures.

For the determination of neutron activation it is desirable to perform the neutron transport calculations with a method which accurately treats the self shielding of small, highly absorbing regions which are likely to be important contributors to the activation source. However, since the region that is highly activated is usually relatively localized around the neutron source, the requirement for treating complex three-dimensional geometries may be relaxed.

For the activation gamma ray transport calculation, it is desirable to use a method which models complex geometries accurately since the shielding and other structural configurations between the activated regions and radiation sensitive areas are likely to be quite complex. Therefore, it is necessary that the gamma ray shielding module of the code system treat complex three-dimensional geometries. To satisfy these requirements, a code system employing the two-dimensional discrete ordinates program, DØT, for the neutron transport module and the point kernel integration program, KAPV, for the gamma ray shielding module was developed. The NAP code is used for the activation and decay chain module.

In the following sections the input and output of each of the component programs are described separately in detail and the overall operation of the code system is discussed and the manner in which the codes are coupled is described. In the final section a sample problem for the code system is presented.

## 2.2 Neutron Transport Module

### 2.2.1 Operating Instructions

It is the purpose of the neutron transport module of the INAP code system to determine the neutron distribution for space and energy in specified material regions from a volume distributed neutron source or an incident neutron flux. For the Engineering System this function is performed by the DØT discrete ordinates transport code developed by the Computing Technology Center at ORNL. The basic methods and operation of this program have not been changed in the INAP version and the INAP user is referred to Reference 2 for instructions in using this program; Reference 3 for quadrature sets and other useful information; and References 4, 5 and 6 for the details of the numerical approximation. However, modifications have been made in the code to integrate it into the system and various modifications have been made and options added to improve the convenience of using the program. In this section those modifications will be discussed and information which will be helpful in using the program in the INAP system will be presented.

DØT solves the time independent linear transport equation in two-space dimensions with general anisotropic scattering. Numerical solutions may be obtained for forward or adjoint and homogeneous or inhomogeneous problems in either  $r, z$ ;  $x, y$ ; or  $r, \theta$  coordinate systems. For the INAP systems, the inhomogeneous, forward problem in an  $r, z$  coordinate system will usually be of greatest interest. The source may be isotropic and volume distributed or a specified angular dependent boundary source at the right or top boundaries. Vacuum, reflective, periodic, white or albedo boundary conditions may be specified, cross sections may be input from a library tape and/or from cards.

The INAP version of DØT is derived from the original DØT program released by ORNL in 1967 and packaged by RSIC as CCC 89A and B. In addition, some but not all of the features of DØT II (packaged by RSIC as CCC 89C) were also added. The following is a list of the differences between the INAP version and the CCC 89A and B versions at RSIC:

1. The space point scaling feature of the DØT II program is incorporated into DØT/INAP.

2. The capability to accept a first collision source is in DØT/INAP as it is in DØT II.

3. DØT/INAP does not write a gamma source tape.

In addition, DØT/INAP will:

4. Compute average energy, normalized integral energy spectrum, and differential energy spectrum on option.

5. Compute response functions by energy group and interval with conversion factors input in the 29\* array.

6. Permit boundary flux to be input by angle and energy once only for all intervals.

7. Compute activities for all mesh intervals.

8. Accept NAMELIST input for all variables which are not input by array.

9. Accept density factors in the 33\* array for problems involving material regions of variable density.

10. Perform the same number of outer iterations regardless of whether or not angular fluxes are saved or printed.

11. Print angular fluxes, if desired, for only those regions specified by the 31\* and 32\* array.

12. Is capable of problem restart after any group within any outer iteration, i.e., do not have to wait until the completion of the outer iteration.

13. Compute average flux  $\left( \text{i.e., } \int_v \frac{\phi(r, E) d\bar{r}}{\int_v d\bar{r}} \right)$  by group in each zone and prepare input for the next module in the INAP system.

#### 2.2.1.1 Flow Diagram and Variable Definitions

On overall flow diagram of DØT/INAP giving the subroutine call sequence is presented in Figure 2.2-1. In addition, the function of each subroutine and the variables defined in the subroutine are presented in the following pages.

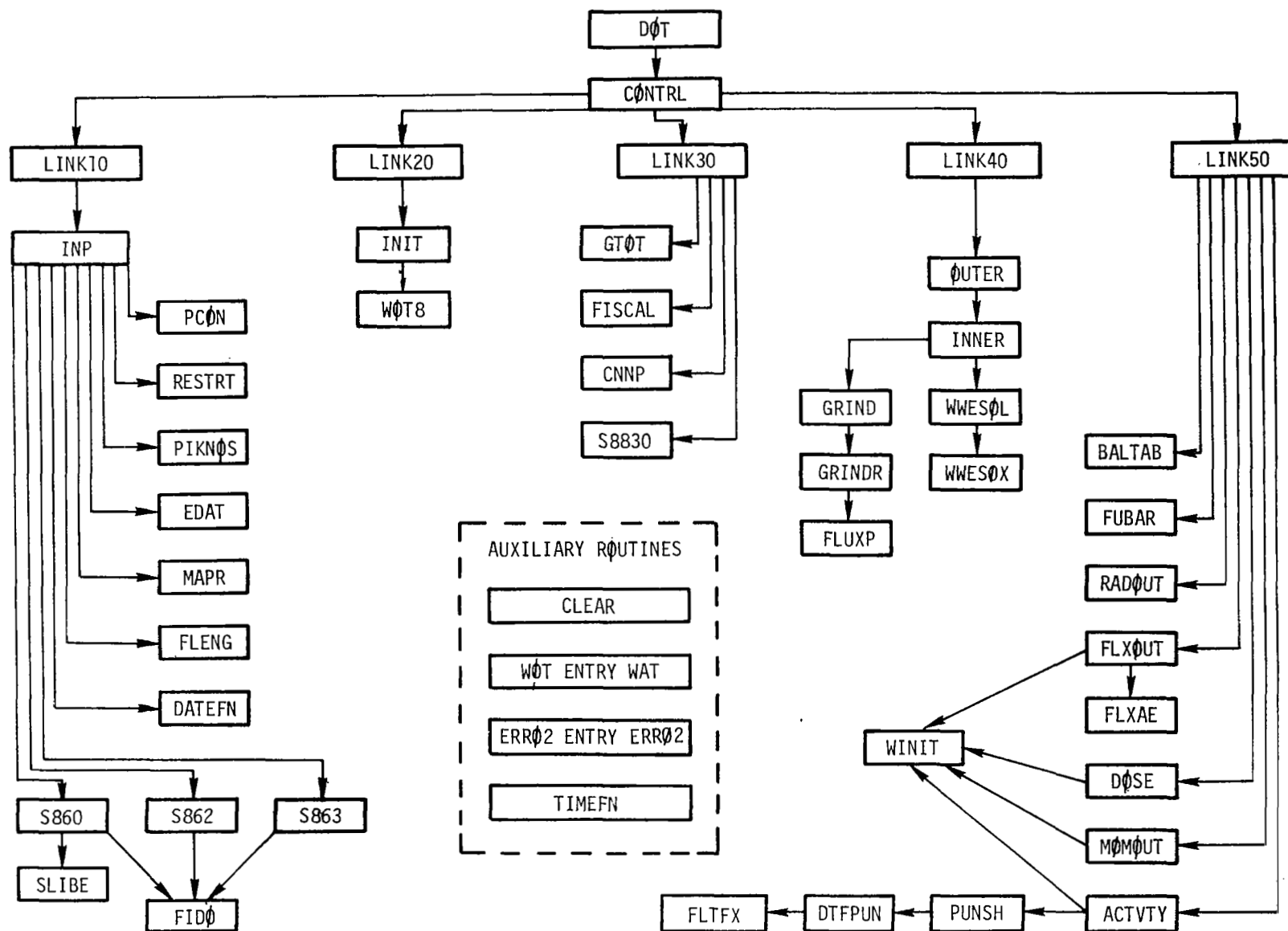


FIGURE 2.2.-1 FLOW CHART FOR DØT

## DEFINITION OF ROUTINES IN DØT

DØT        MAIN PROGRAM, CALLS CØNTRL

CLEAR     CALL CLEAR (VAL, X, N)  
          SET \*N\* WORDS OF ARRAY \*X\* TO \*VAL\*  
          CALLED BY - INP, INNER, INIT, CNNP

CØNTRL    CALLS THE VARIOUS OVERLAYS. INCREMENTS THE OUTER ITERATION  
          COUNTER AND TESTS IT AGAINST THE MAXIMUM. SETS FLAG (CVT)  
          WHICH CAUSES PRINT-OUT OF ANGULAR FLUXES  
          ROUTINES CALLED - LINK10, LINK20, LINK30, LINK40, LINK50,  
          CALLED BY - DØT

ERRØ2    (ERRØ2)  
          PRINTS ERROR MESSAGE AND STOPS  
          CALLED BY - INP, INIT, EDAT, CNNP

TIMEFN    CALL TIMEFN (HEAD)  
          USER DELIVERS FOUR WORD HOLERITH HEADER, ROUTINE PRINTS OUT  
          HEADER ALONG WITH PROCESSOR TIME.  
          CALLED BY - INP, INIT, ØUTER, LINK30  
          UNIVAC 1108 SYSTEM ROUTINES CALLED - ETIME, ETIMEF

WØT      (WAT)  
          WRITES OUT ONE, TWO, OR THREE DIMENSIONAL ARRAYS, INCLUDING  
          SUPPLIED HEADERS  
          ·CALLED BY - WINIT, S862, INIT,

LINK10    MAIN PROGRAM OF INPUT LINK  
          ROUTINE CALLED - INP  
          CALLED BY - CØNTRL

EDAT      CHECKS TO SEE IF FLUX PER MEV CONVERSION FACTORS ARE IN  
          ORDER AS THEY SHOULD BE  
          ROUTINE CALLED - ERRØ2  
          CALLED BY - INP

FIDØ      PROCESSES THE ARRAY DATA CARDS. EACH TIME FIDO IS CALLED IT  
          PROCESSES AN ENTIRE DATA BLOCK. IT DETERMINES WHAT EACH  
          ARRAY IS, WHERE IT IS TO BE STORED, AND STORES THE ENTRIES  
          IN THE PROPER LOCATIONS. IT RETURNS CONTROL TO THE CALLING  
          SUBROUTINE WHEN A (T) IN THE SECOND SUBFIELD IS ENCOUNTERED.  
          MACHINE DEPENDENT FEATURE - USES DECODE IN ORDER TO READ  
          EACH CARD IN TWO DIFFERENT FORMATS.  
          CALLED BY - INP, S860, S862, S863

## DEFINITION OF ROUTINES IN DØT

**FLENG** PRINTS STORAGE REQUIREMENT MESSAGES  
MACHINE DEPENDENT FEATURE - MAKES USE OF SIX CHARACTER WORD  
SIZE TO STORE CHARACTER STRINGS.  
CALLED BY - INP

**INP** READS NAMELIST DATA. PRINTS THIS DATA WITH DEFINITIONS.  
SETS UP STARTING LOCATIONS IN THE BUCKET FOR THE ARRAYS.  
PRINTS MESSAGES REGARDING CORE REQUIREMENTS. CALLS ROUTINE  
TO SET FIELD LENGTH. CALLS ROUTINES WHICH CAUSE DATA ARRAYS  
TO BE READ IN. CALLS ROUTINES TO COMPUTE HIGHER ORDER  
SCATTERING CONSTANTS, TO EDIT ENERGIES, TO DETERMINE WHICH  
MESH INTERVALS ANGULAR FLUX IS TO BE SAVED FOR, TO PRINT OUT  
MAPS OF ZONE BY MESH INTERVAL AND MATERIAL BY ZONE.  
ROUTINES CALLED - ERRØ2, FIDØ, CLEAR, RESTRT, FLENG, S860,  
S862, S863, PCØN, EDAT, PIKNØS, MAPR, DATEFN,  
TIMEFN  
CALLED BY - LINK10

**DATEFN** CALL DATEFN (DATE)  
RIGHT NOW A DUMMY ROUTINE. INTENDED TO RETURN DATE AS A  
HOLERITH STRING OF NOT MORE THAN 12 CHARACTERS  
CALLED BY - INP

**MAPR** PRINTS MAPS OF ZONE NUMBER BY INTERVAL AND MATERIAL NUMBER  
BY ZONE  
MACHINE DEPENDENT FEATURES - VARIABLE FMT IS USED FOR A  
VARIABLE FORMAT IN ORDER TO PRINT HOLERITH XRR  
ON THE LOWER RIGHT HAND CORNER OF THE MAPS.  
THE ENCODE FEATURE IS USED TO SET UP THE FORMAT.  
CALLED BY - INP

**PCØN** COMPUTES HIGHER ORDER SCATTERING CONSTANTS  
CALLED BY - INP

**PIKNØS** DETERMINES FOR WHICH RADIAL AND AXIAL MESH INTERVALS THE  
ANGULAR FLUX IS TO BE SAVED. THE FLUXES WILL BE SAVED WHERE  
THE SELECTED RADIAL AND AXIAL INTERVALS INTERSECT.  
CALLED BY - INP

**RESTRT** FOR A FIRST COLLISION SOURCE TYPE PROBLEM (IØ4=6) THIS  
ROUTINE READS IN THE RADII, MATERIAL NUMERS BY ZONE, AND  
ZONE NUMBERS BY INTERVAL FROM FILE \*NAFT\* IF THE USER DID  
NOT ENTER THESE ARRAYS VIA CARDS.  
CALLED BY - INP

**SLIBE** READS CROSS SECTIONS FROM LIBRARY TAPE  
CALLED BY - S860

DEFINITION OF ROUTINES IN DØT

- S860 : CALLS FIDØ TO READ IN CROSS SECTION CARD INPUT. CALLS SLIBE TO READ IN X-SECTS FROM LIBRARY TAPE. PERFORMS ADJOINT REVERSALS ON CROSS SECTIONS IF NECESSARY. WRITES CROSS SECTIONS ON SCRATCH FILE NCRI  
ROUTINES CALLED - FIDØ, SLIBE  
CALLED BY - INP
- S862 CALLS FIDØ TO READ IN DISTRIBUTED SOURCE FROM CARDS. PRINTS OUT DISTRIBUTED SOURCE. FORMS A SCRATCH FILE CONSISTING OF CROSS SECTIONS (NOT YET MIXED) AND DISTRIBUTED SOURCE. ALSO CALLS FIDØ TO READ FLUX GUESS.  
ROUTINES CALLED - FIDØ, WØT  
CALLED BY - INP
- S863 CALLS FIDØ TO READ IN BOUNDARY SOURCE. WRITES BOUNDARY SOURCE ON FILE NBSØ.  
ROUTINE CALLED - FIDØ  
CALLED BY - INP
- LINK20 MAIN PROGRAM OF DATA EDIT LINK  
ROUTINE CALLED - INIT  
CALLED BY - CØNTRL
- INIT EDITS DATA. CHECKS MU,S AND ETA,S TO MAKE SURE THEY ARE NON-ZERO. COMPUTES WEIGHT\*MU ARRAY, W1, AND WEIGHT\*ETA1ARRAY, W2 COMPUTES MU-BAR AND MU-MATES ARRAYS, M3, M6. COMPUTES ETA-MATES, M4. PRINTS WEIGHTS, COSINES, AND THESE ARRAYS WHICH HAVE BEEN COMPUTED. WRITES INFORMATION ON ANGULAR FLUX TAPE IF IT IS TO BE SAVED. PERFORMS ADJOINT REVERSALS ON K7, V7. MIXES AND PRINTS OUT CROSS SECTIONS. MODIFIES GEOMETRY. COMPUTES AREAS AND VOLUMES, FISSION SPECTRUM, DISTRIBUTED SOURCE DATA. PRINTS DISTRIBUTED SOURCE BY GROUP. COMPUTES BOUNDARY SOURCE DATA. PRINTS OUT RIGHT AND/OR TOP BOUNDARY SOURCE BY GROUP. COMPUTES FISSIONS. PRINTS MIXING TABLES, RADII, MATERIAL BY ZONE, FISSION SPECTRUM, VELOCITIES, SEARCH DATA, ALBEDOS.  
ROUTINES CALLED - ERRØ2, WØT, WØT8, TIMEFN, CLEAR  
CALLED BY - LINK20
- WØT8 PRINTS UP TO EIGHT SINGLY SUBSCRIBTED INTEGER OR FLOATING POINT ARRAYS. THE ARRAYS CAN BE OF VARYING LENGTHS. THE ARGUMENTS ARE IN PAIRS. THE ODD NUMBERED ARGUMENTS ARE THE ADDRESSES OF THE ARRAYS AND THE EVEN NUMBERED ARGUMENTS ARE THE LENGTHS. IF A LENGTH IS ZERO NO ARRAY IS PRINTED IN THE CORRESPONDING FIELD.  
CALLED BY - INIT
- LINK30 MAIN PROGRAM OF LINK THAT PERFORMS GROUP TOTAL CALCULATIONS, COMPUTES FISSION SUMS, NORMALIZES FISSIONS, PERFORMS OUTER CONVERGENCE TESTS, GIVES MONITOR PRINT-OUT. LINK30 PERFORMS

## DEFINITION OF ROUTINES IN DØT

A FISSION SWITCH BETWEEN THE F0 AND F2 ARRAYS.  
WRITES FISSION RECORD ON RESTART TAPE, WRITES PSEUDO END OF  
FILE RECORD ON RESTART TAPE.  
WHEN RESTARTING A RUN THIS ROUTINE READS THE RESTART TAPE  
IN ORDER TO SETUP THE OLD FLUX FILE  
ROUTINES CALLED - GTØT, FISCAL, CNNP, S8830, TIMEFN  
CALLED BY - CØNTRL

CNNP PERFORMS OUTER CONVERGENCE TESTS. IN THE CASE OF SEARCH  
OPTIONS A NEW EIGENVALUE WILL BE COMPUTED WHEN REQUIRED.  
ROUTINES CALLED - ERRØ2, CLEAR  
CALLED BY - LINK30

FISCAL COMPUTES FISSION SUMS AND NORMALIZES FISSIONS. COMPUTES  
LAMBDA  
CALLED BY LINK30

GTØT COMPUTES GROUP TOTALS. COMPUTES NEUTRON BALANCE.  
CALLED BY LINK30

S8830 PERFORMS MONITOR PRINT-OUT FOLLOWING EACH OUTER ITERATION.  
CALLED BY - LINK30

LINK40 MAIN PROGRAM OF THE ITERATION LINK  
ROUTINE CALLED - ØUTER  
CALLED BY - CØNTRL

FLUXP PRINTS OUT ANGULAR FLUXES AND/OR WRITES ANGULAR FLUX TAPE.  
CALLED BY - GRIND (CALLED BY GRINDR IN FORTRAN VERSION)

GRIND (COMPASS - CDC MACHINE LANGUAGE) COMPUTES THE ANGULAR AND  
TOTAL FLUXES. FOR EACH INNER ITERATION THIS ROUTINE IS  
CALLED TWICE BY INNER, ONCE FOR THE TOP BOUNDARY AND ONCE  
FOR THE LOWER BOUNDARY  
ROUTINE CALLED - FLUXP  
CALLED BY - INNER  
(FØRTRAN) IN THE FØRTRAN VERSION GRIND SETS UP THE ARGUMENTS  
FOR GRINDR WHICH IS THE FORTRAN EQUIVALENT OF GRIND

GRINDR IN THE VERSION WITH MACHINE LANGUAGE GRIND THIS IS A DUMMY  
ROUTINE WHICH IS NOT CALLED. IN THE FØRTRAN VERSION GRINDR  
IS THE FORTRAN EQUIVALENT OF GRIND. GRINDR CALLS FLUXP AND  
IS CALLED BY GRIND.

INNER PERFORMS A COMPLETE INNER ITERATION FOR EACH GROUP.  
ESTABLISHES BOUNDARY CONDITION FOR TOP AND BOTTOM BOUNDARY,  
CALLS GRIND TO COMPUTE FLUX AND CURRENT, COMPUTES NEUTRON

## DEFINITION OF ROUTINES IN DØT

SUMS, LEAKAGES. SCALES TOTAL FLUX, BOUNDARY FLUX, CURRENT, LEAKAGES. PERFORMS INNER CONVERGENCE TESTS. RETURNS TO OUTER WHEN THE INNER CONVERGENCE TESTS ARE SUCCESSFUL OR THE INNER ITERATION MAXIMUM IS REACHED. WHEN POINT SCALE OPTION IS USED, INNER CALLS THE POINT SCALE ROUTINE, WWESØL  
ROUTINES CALLED - GRIND, WWESØL  
CALLED BY - ØUTER

ØUTER PERFORMS OUTER ITERATION. FOR EACH GROUP READS IN PROPER X-SECTS, FLUXES, CURRENTS, SOURCES FROM SCRATCH FILES. PERFORMS SOME INITIALIZATION. CALLS INNER. AFTER RETURN FROM INNER OUTER SAVES NECESSARY QUANTITIES. ON OPTION OUTER PRINTS SOME ITERATION INFORMATION ON THE SCOPE. THIS ROUTINE ALSO CHANGES FROM POINTWISE TO INTEGRAL CONVERGENCE ON OPTION  
ROUTINES CALLED - INNER, TIMEFN  
SYSTEM ROUTINE CALLED - SSWTCH  
CALLED BY - LINK40

WWESØL (COMPASS - CDC MACHINE LANGUAGE) PERFORMS POINT SCALING ON FLUXES  
(FØRTRAN) IN FØRTRAN VERSION WWESOL SETS UP THE ARGUMENTS FOR WWESØX WHICH IS THE FORTRAN EQUIVALENT OF WWESØL

WWESØX IN THE VERSION WITH MACHINE LANGUAGE WWESØL THIS IS A DUMMY ROUTINE WHICH IS NOT CALLED. IN THE FØRTRAN VERSION WWESOX IS THE FØRTRAN EQUIVALENT OF WWESØL. WWESØX IS CALLED BY WWESØL.

LINK50 MAIN PROGRAM FOR OUTPUT LINK  
ROUTINES CALLED - BALTAB, RADØUT, FLXØUT, DØSE, MØMØUT, ACTVTY, FLXAE, FUBAR  
CALLED BY - CØNTRL

FUBAR COMPUTES VOLUME WEIGHTED FLUX BY ZONE  
CALLED BY LINK50

ACTVTY COMPUTES ACTIVITIES. CALLS ROUTINES TO PRINT, PUNCH ACTIVITIES  
ROUTINES CALLED - PUNSH, WINIT  
CALLED BY - LINK50

BALTAB PRINTS OUT BALANCE TABLES  
CALLED BY - LINK50

DOSE COMPUTES DOSE. CALLS ROUTINE TO PRINT OUT DOSES  
ROUTINE CALLED - WINIT  
CALLED BY - LINK50

# DEFINITION OF ROUTINES IN DOT

DTFPUN PUNCHES CARDS IN FIDØ INPUT FORMAT  
ROUTINE CALLED - FLTFX  
CALLED BY - PUNSH

FLTFX CONVERTS FLOATING POINT NUMBER TO TWO INTEGER PARTS,  
EXPONENT AND MANTISSA  
CALLED BY - DTFPUN

FLXAE COMPUTES AND PRINTS OUT FLUX ABOVE ENERGY  
CALLED BY - LINK50, FLXØUT

FLXØUT PRINTS OUT FLUX BY GROUP AND INTERVAL. COMPUTES AND PRINTS  
INTEGRATED FLUX. COMPUTES AND PRINTS OUT ENERGY\*FLUX BY  
GROUP AND INTERVAL. PRINTS FISSION EDIT. COMPUTES AND PRINTS  
AVERAGE ENERGY, FLUX PER MEV.  
ROUTINES CALLED - FLXAE, WINIT  
CALLED BY - LINK50

MØMØUT COMPUTES AND PRINTS FLUX MOMENTS  
ROUTINE CALLED - WINIT  
CALLED BY - LINK50

PUNSH SETS UP EACH CARD TO BE PUNCHED BY DTFPUN IN FIDØ INPUT  
FORMAT. UTILIZES REPEATS.  
ROUTINE CALLED - DTFPUN  
CALLED BY - ACTVTY

RADØUT PRINTS OUT RADII AND AVERAGE RADII  
CALLED BY - LINK50

WINIT CALLS ROUTINE TO PRINT OUT TWO DIMENSIONAL ARRAY  
ROUTINE CALLED - WAT  
CALLED BY - ACTVTY, DØSE, FLXØUT, MØMØUT

# DØT VARIABLES

\*\*\*\*\* CØMMØN BLØCK / TAPES /

LOCATION	VARIABLE	DEFINITION
0	NINP	LOGICAL INPUT FILE.
1	NØUT	LOGICAL OUTPUT FILE.
2	NCRI	CROSS SECTION AND DISTRIBUTED SOURCE LOGICAL FILE.
3	NFLUX1	FLUX FILE.
4	NSCRAT	SCRATCH FILE.
5	NAFT	ANGULAR FLUX FILE.
6	NBSØ	BOUNDARY SOURCE FILE.
7	NFLSV	TAPE TO SAVE TOTAL FLUXES ON.
8	NPSØ	FIRST COLLISION SOURCE TAPE FILE

\*\*\*\*\* CØMMØN BLØCK / JØBTYP /

LOCATION	VARIABLE	DEFINITION
0	JØBTYP	1 = NEW PROBLEM. 2 = RESTART 3 = PROCESS OUTPUT TAPES GENERATED BY DØT (NOT IMPLEMENTED).

\*\*\*\*\* CØMMØN BLØCK / MØMENT /

LOCATION	VARIABLE	DEFINITION
0	MØMENT	ONLY USED WHEN IAFI = 2 AND A03 NOT EQUAL 0 0 = DO NOT PRINT FLUX MOMENTS. 1 = PRINT FLUX MOMENTS.

\*\*\*\*\* CØMMØN BLØCK / NERR /

LOCATION	VARIABLE	DEFINITION
0	NERR	NUMBER OF FIDØ INPUT ARRAYS WITH ERRORS.

# DPT VARIABLES

\*\*\*\*\* COMMON BLOCK / IBSS /

LOCATION	VARIABLE	DEFINITION
0	IBSS	NUMBER OF ENTRIES IN BOUNDARY SOURCE ARRAY.
1	ISTEPR	NUMBER OF RIGHT BOUNDARY SOURCE ENTRIES PER GROUP. 0 IF IRBC NOT 4 OR -4 $((A04*(A04+4))/4 + A04/2)*JM$ IF IRBC = 4 $(A04*(A04+4))/4 + A04/2$ IF IRBC = -4, I.E. PUT SAME VALUES FOR ALL JM MESH POINTS.
2	ISTEPT	NUMBER OF TOP BOUNDARY SOURCE ENTRIES PER GROUP. 0 IF ITBC NOT 4 OR -4 $((A04*(A04+4))/4)*IM$ IF ITBC = 4 $(A04*(A04+4))/4$ IF ITBC = -4, I.E. PUT SAME VALUES FOR ALL IM MESH POINTS.
3	JRX	= 1 IF IRBC = 4,      = JM IF IRBC = -4
4	JTX	= 1 IF ITBC = 4,      = IM IF ITBC = -4

\*\*\*\*\* COMMON BLOCK / ISIZE1 /

LOCATION	VARIABLE	DEFINITION
0	ISIZE1	$(A04*(A04+4))/4 + A04/2$
1	ISIZE2	$(A04*(A04+4))/4 - A04/2$
2	JFISC	= 1 MEANS FIRST OUTER PASS. DO NOT FORM GROUP TOTALS AND DO NOT CALL OUTER CONVERGENCE ROUTINE, CNNP. = 2 MEANS FORM GROUP TOTALS AND PERFORM OUTER CONVERGENCE TESTS.

\*\*\*\*\* COMMON BLOCK / OTHER /

LOCATION	VARIABLE	DEFINITION
0	FLAG	USED IN INNER AND GRIND. FLAG = -1.0 MEANS PERFORM COMPUTATIONS FOR TOP BOUNDARY. FLAG = 1.0 MEANS PERFORM COMPUTATIONS FOR BOTTOM BOUNDARY.
1	M11	LOWER LIMIT ON ANGLES. = 1 WHEN FLAG = -1.0 = $MM/2 + 1$ WHEN FLAG = 1.0
2	M21	UPPER LIMIT ON ANGLES. = $MM/2$ WHEN FLAG = -1.0 = $MM$ WHEN FLAG = 1.0

# DOT VARIABLES

\*\*\*\*\* COMMON BLOCK / OTHER /

LOCATION	VARIABLE	DEFINITION
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\*\*\*\*\* COMMON BLOCK / IRES /

LOCATION	VARIABLE	DEFINITION
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0	IRES	0 - NO EFFECT. 1 - SAVE RESTART FLUXES ON LOGICAL UNIT *NFLSV*
1	NGDONE	USED WHEN RESTARTING A PROBLEM. THE NUMBER OF GROUPS FOR WHICH THE COMPUTATIONS HAVE BEEN COMPLETED ON THE PRESENT OUTER ITERATION
2	TIME	PRESENT PROCESSOR TIME.

\*\*\*\*\* COMMON BLOCK / NIDONE /

LOCATION	VARIABLE	DEFINITION
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0	NIDONE	USED WHEN RESTARTING A PROBLEM. THE NUMBER OF OUTER ITERATIONS WHICH HAVE BEEN COMPLETED.
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\*\*\*\*\* COMMON BLOCK / TEST /

LOCATION	VARIABLE	DEFINITION
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0	IGTEST	IF NON-ZERO, STOP THE PROBLEM AFTER THE CALCULATIONS FOR GROUP *IGTEST* HAVE BEEN COMPLETED.
1	ITTEST	THE OUTER ITERATION ON WHICH TO STOP THE PROBLEM AFTER GROUP *IGTEST* IS DONE.

\*\*\*\*\* COMMON BLOCK / DINP /

LOCATION	VARIABLE	DEFINITION
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0	DINP	NOT USED
1	A01	(ID) PROBLEM IDENTIFICATION NUMBER
2	A02	(ITH) 0=REGULAR CALCULATION, 1=ADJOINT CALCULATION
3	A03	(ISCT) ORDER OF LEGENDRE EXPANSION

# DØT VARIABLES

\*\*\*\*\* COMMON BLOCK / DINP /

LOCATION	VARIABLE	DEFINITION
4	A04	(ISN) ORDER OF SN QUADRATURE
5	IGE	GEOMETRY FLAG
6	IZM	NUMBER OF MATERIAL ZONES
7	IM	NUMBER OF RADIAL MESH INTERVALS
10	JM	NUMBER OF AXIAL MESH INTERVALS
11	I04	PROBLEM TYPE
12	EV	FIRST EIGENVALUE GUESS FOR SEARCH
13	EVM	EIGENVALUE MODIFIER
14	EPS	GENERAL CONVERGENCE CRITERION
15	B01	(ILBC) LEFT BOUNDARY CONDITION
16	B02	IABS(IRBC) IRBC IS RIGHT BOUNDARY CONDITION
17	B03	IABS(ITBC) ITBC IS TOP BOUNDARY CONDITION
20	B04	(IBBC) BOTTOM BOUNDARY CONDITION
21	M07	(IFLX) FLUX INPUT TRIGGER
22	FXT	(MODE) FLUX CALCULATION MODE
23	MT	TOTAL NUMBER OF MATERIALS INCLUDING MIXTURES
24	M01	(MS) LENGTH OF MIXTURE TABLE
25	MCR	NUMBER OF CROSS SECTION SETS FROM CARDS
26	MTP	NUMBER OF CROSS SECTION SETS FROM LIBRARY TAPE
27	IZ	NUMBER OF RADIAL ZONES FOR THICKNESS SEARCH
30	JZ	NUMBER OF AXIAL ZONES FOR THICKNESS SEARCH
31	S02	(IEVT) TYPE OF PARAMETRIC EIGENVALUE SEARCH
32	S03	(PEV) PARAMETRIC EIGENVALUE FOR SEARCH
33	IGM	NUMBER OF ENERGY GROUPS
34	IHT	POSITION OF SIGMA TOTAL IN X-SECT TABLE
35	IHS	POSITION OF SIGMA G-G IN X-SECT TABLE
36	ITL	CROSS SECTION TABLE LENGTH

# DØT VARIABLES

\*\*\*\*\* CØMMØN BLØCK / DINP /

LOCATION	VARIABLE	DEFINITION
37	S01	(XNF) NORMALIZATION FACTOR
40	M05	(NACT) NUMBER OF ACTIVITIES DESIRED
41	M06	(IDFS) METHOD OF INPUT FOR DISTRIBUTED FIXED SOURCE
42	S04	(ITII) INITIAL INNER ITERATION MAXIMUM
43	D05	OUTER ITERATION MAXIMUM. SUBTRACT ONE IF IAFT NOT 0
44	G07	(ITMI) INNER ITERATION MAXIMUM PER GROUP
45	G05	(ENB) EPSILON FOR NEUTRON BALANCE
46	G06	(EPW) EPSILON FOR POINTWISE FLUX ERROR
47	LAL	(XLAL) EPSILON FOR SEARCH
50	LAH	(XLAH) UPPER LIMIT ON (LAMBDA-1.0) USED IN LINEAR SEARCH
51	PØD	PARAMETER OSCILLATION DAMPER
52	EPSA	EPSILON FOR NEW PARAMETERS
53	IAFT	ANGULAR FLUX OUTPUT TRIGGER
54	IEØPT	(IENG) ENERGY CALCULATION TRIGGER
55	IDSØPT	(INDS) FLUX TO DOSE CALCULATION TRIGGER
56	NPUNCH	(NPUN) PUNCH INTEGRATED ACTIVITY TRIGGER
57	NØGM	NOT USED
60	NSCTI	(NSCI) RADIAL INTERVAL ANGULAR FLUX PRINT TRIGGER
61	NSCTJ	(NSCJ) AXIAL INTERVAL ANGULAR FLUX PRINT TRIGGER
62	IGITER	(IGIT) USE IIITER AS INNER ITERATION MAXIMUM IF PRESENT GROUP INDEX IS LESS THAN OR EQUAL TO IGITER
63	IIITER	(IIIT) INNER ITERATION MAXIMUM TO BE USED IF THE PRESENT GROUP INDEX IS LESS THAN OR EQUAL TO IGITER
64	IPRINT	NOT USED
65	ISIZE	(LIM1,LFL1,LFL2) NUMBER OF WORDS IN BLANK CØMMØN

## DØT VARIABLES

\*\*\*\*\* CØMMØN BLØCK / DØT1 /

LOCATION	VARIABLE	DEFINITION
0	ALA	LAMBDA
1	AV	NOT USED
2	AVP	NOT USED
3	AVR	NOT USED
4	B05	NOT USED
5	B06	NOT USED
6	B07	USED FOR INTERNAL COMPUTATION
7	CNT	CONVERGENCE TRIGGER FOR LAMBDA
10	CTL	SUM OF W2 FOR NEGATIVE W2
11	CVT	NORMALLY ZERO. SET TO ONE ON THE OUTER PASS THAT SAVES ANGULAR FLUXES.
12	DEN	TEMPORARY
13	DENØM	TEMPORARY
14	DISCR	TEMPORARY
15	D01	NOT USED
16	D02	NOT USED
17	D03	NOT USED
20	D04	NOT USED
21	EQ	TEMPORARY
22	EQA	TEMPORARY
23	EQB	TEMPORARY
24	EQC	TEMPORARY
25	EQR	DP/DL FOR PREVIOUS ITERATION
26	EQS	DP/DL
27	EVA	ABS(EV-EV1)
30	EVB	ABS(EV-EV2)
31	EVP	PREVIOUS EIGENVALUE

# DØT VARIABLES

\*\*\*\*\* CØMMØN BLØCK / DØT1 /

LOCATION	VARIABLE	DEFINITION
32	EVPP	EIGENVALUE FOR TWO ITERATIONS BACK
33	EV1	TEMPORARY
34	EV2	TEMPORARY
35	E01	TEMPORARY
36	E02	TEMPORARY
37	E03	TEMPORARY
40	E04	TEMPORARY
41	E05	TEMPORARY
42	F	1.4142
43	GBAR	GROUP INDICATOR FOR FILE MOTION IN SUBROUTINE ØUTER
44	IAFP	FLAG WHICH IS SET IN ORDER TO CAUSE ANGULAR FLUX TO BE SAVED
45	IBB	B04 + 1 BOTTOM BOUNDARY FLAG
46	IBL	B01 + 1 LEFT BOUNDARY FLAG
47	IBR	B02 + 1 RIGHT BOUNDARY FLAG
50	IBT	B03 + 1 TOP BOUNDARY FLAG
51	IFØT	0 = FLUX, FLUX MOMENTS STORED ENTIRELY IN CORE 1 = FLUX, FLUX MOMENTS STORED ON DISK/TAPE
52	IGEP	IGE + 1
53	IGK	ENERGY GROUP INDEX, =IGM IF IFOT=0, =1 IF IFOT=1,
54	IGP	IGM + 1
55	IGV	PRESENT GROUP INDEX
56	IG1	POINTS TO PROPER GROUP COLUMN IN VARIOUS ARRAYS THAT ARE ENTIRELY IN CORE IF IFOT=0, OR ON DISK/TAPE IF IFOT=1, WHERE ONLY ENOUGH CORE IS ALLOCATED FOR THE DATA FOR ONE GROUP
57	IHG	ITL*IGM (TABLE LENGTH)*GROUPS
60	II	INNER ITERATION COUNT FOR THE PRESENT GROUP
61	IMJM	IM*JM (RADIAL MESH)*(AXIAL MESH)

# DOT VARIABLES

\*\*\*\*\* COMMON BLOCK / DOT1 /

LOCATION	VARIABLE	DEFINITION
62	IP	IM + 1
63	IT	INITIAL TIME, NOT USED
64	ITEMP	TEMPORARY
65	ITP	NOT USED
66	IZP	IZM + 1
67	ITEMP1	TEMPORARY
70	ITEMP2	TEMPORARY
71	JP	JM + 1
72	K01	NOT USED
73	K02	NOT USED
74	K03	NOT USED
75	K04	NOT USED
76	K05	NOT USED
77	K06	NOT USED
100	K07	NOT USED
101	LAP	LAMBDA FOR PREVIOUS EIGENVALUE
102	LAPP	LAMBDA FOR TWO ITERATIONS BACK
103	LAR	LAMBDA FOR PREVIOUS ITERATION
104	LC	LOOP COUNT TOTAL INNER ITERATIONS IN A SINGLE OUTER ITERATION
105	MBAR	TEMPORARY
106	MJMK	= IMJM IF I04 = 0, OTHERWISE = 1
107	ML	MCR + MTP, TOTAL NUMBER OF INPUT X-SECT SETS
110	MM	(A04*(A04+4))/2, NUMBER OF ANGLES
111	MMIM	MM*IM
112	MMIP	MM*IP
113	MMJM	MM*JM

# DØT VARIABLES

\*\*\*\*\* CØMMØN BLØCK / DØT1 /

LOCATION	VARIABLE	DEFINITION
114	NB	NOT USED
115	NBAR	TEMPORARY FOR ANGULAR FLUX
116	NGØTØ	WHEN USED IN INNER NGØTØ = 1 MEANS WORKING ON UPPER ANGLES AND NGØTØ = 2 MEANS WORKING ON LOWER ANGLES ALSO USED AS OUTER CONVERGENCE TEST TRIGGER WHERE 1 = CONVERGED, 2 = NOT CONVERGED, 3 = GO BACK FOR AN INIT PASS.
117	NØM	NØMA*IMJM
120	NØMA	(A03*(A03+3))/2
121	NUM	TEMPORARY
122	PBAR	TEMPORARY GROUP INDEX
123	P02	OUTER ITERATION COUNT
124	P07	NOT USED
125	SBAR	TEMPORARY
126	SIM	SQRT(IM)
127	SIMJM	SQRT(IMJM)
130	SJM	SQRT(JM)
131	SBAR1	TEMPORARY
132	SK7	SUM OVER K7 OVER ALL GROUPS
133	SUMW1	SUM OF W1 OVER ALL MM FOR POSITIVE W1
134	SUMW2	SUM OF W2 OVER ALL MM FOR POSITIVE W2
135	TC	NOT USED
136	TEMP	TEMPORARY
137	TI	TIME
140	TEMP1	TEMPORARY
141	TEMP2	TEMPORARY
142	TEMP3	TEMPORARY
143	TEMP4	TEMPORARY

# DØT VARIABLES

\*\*\*\*\* CØMMØN BLØCK / DØT1 /

LOCATION	VARIABLE	DEFINITION
144	T06	0/1=NOT DELTA/DELTA
145	T10	0/1=ISO/ANISO
146	T11	PREVIOUS FISSION TOTAL
147	T12	SELF SCATTER, ISO
150	T15	MM/2
151	T16	MM/2 + 1
152	T17	B02 + B03
153	UP	0/1 = UPSCATTER/NO UPSCATTER
154	UP1	UPSCATTER ERROR
155	UP2	ABS(UP1)
156	VBL	BOTTOM LEAKAGE
157	VHL	HORIZONTAL LEAKAGE
160	VLL	LEFT LEAKAGE
161	VNL	NET LEAKAGE
162	VRL	RIGHT LEAKAGE
163	VTL	TOP LEAKAGE
164	VVL	VERTICAL LEAKAGE
165	V07	SCALE FACTOR
166	V10	ERROR IN SELF SCATTER
167	V11	TOTAL SOURCE FOR THE GROUP
170	V12	EPS*(E0+E1)/IGM INNER ITERATION CONVERGENCE CRITERIA
171	V13	SELF SCATTER, ANISO
172	V14	NOT USED
173	ICØUNT	NOT USED

# DØT VARIABLES

\*\*\*\*\* CØMMØN BLØCK / LØK8 /

THE ENTRIES IN THIS CØMMØN BLØCK POINT TO THE STARTING LOCATIONS IN THE DATA BUCKET OF THE VARIOUS ARRAYS. THE VARIABLE DIMENSION(S) OF EACH ARRAY IS INDICATED ALONG WITH A DESCRIPTION OF THE ARRAY

LOCATION	VARIABLE	DEFINITION
0	LLL(2)	NOT USED
2	LC0	C0(ITL,MT) CROSS SECTION ARRAY FOR CURRENT GROUP
3	LS2	S2(IM,JM) FIXED SOURCE, CALCULATED
4	LB2	B2(MM,JM) FINAL BOUNDARY FLUX (LEFT AND RIGHT)
5	LB4	B4(MM,IM) FINAL BOUNDARY FLUX (TOP AND BOTTOM)
6	LN2	N2(IM,JM,IGK) TOTAL FLUX NEW
7	LA0	A0(IM) RADIAL AREA ELEMENT
10	LA1	A1(JM) AXIAL AREA ELEMENT
11	LA5	AFLUX(IM,T15) ANGULAR FLUX
12	LA7	A7(IGP) NEUTRON BALANCE BY GROUP
13	LB0	B0(MM,JM) INITIAL BOUNDARY FLUX (LEFT AND RIGHT)
14	LB6	B6(MM,IM) INITIAL BOUNDARY FLUX (TOP AND BOTTOM)
15	LS3	S3(IMJM,NØMA) ANISOTROPIC SOURCE
16	LJ3	J3(IMJM,NØMA,IGK) CURRENT
17	LP3	P3(MM,NØMA) DISCRETE VALUES OF PN(THETA)*CØS(M*PSI))
20	LBSR	BSR(ISIZE1,JM) RIGHT BOUNDARY SOURCE
21	LBST	BST(T15,IM) TOP BOUNDARY SOURCE
22	LBSS	BSS(IGP) TEMPORARY USED IN COMPUTATION OF TOTAL FIXED SOURCE WHEN THERE IS A BOUNDARY SOURCE.
23	LF0	F0(IM,JM) OLD FISSIONS, ALSO USED AS TEMPORARY IN OUPUT SECTION OF CODE.
24	LF2	F2(IM,JM) NEW FISSIONS, ALSO USED AS TEMPORARY IN OUTPUT SECTION OF CODE.
25	LG2	G2(MM,IM) GEOMETRIC FUNCTIONS
26	LIO	IO(MS) MIXTURE NUMBERS

# DOT VARIABLES

\*\*\*\*\* COMMON BLOCK / LØK8 /

LOCATION	VARIABLE	DEFINITION
27	LI1	I1(MS) MIXTURE INGREDIENTS
30	LI2	I2(MS) MIXTURE FACTORS
31	LI3	I3(MTP) IDENTIFICATION NUMBERS FOR CROSS SECTIONS ON LIBRARY TAPE
32	LI7	I7(IZM) SELF-SCATTER ERROR BY ZONE
33	LK6	K6(IGM) FISSION SPECTRUM (EFFECTIVE)
34	LK7	K7(IGM) FISSION SPECTRUM (INPUT)
35	LM0	M0(IM,JM) ZONE NUMBERS BY MESH INTERVAL
36	LM2	M2(IZM) MATERIAL NUMBERS BY ZONE
37	LM3	M3(MM) MU-BAR
40	LM4	M4(MM) ETA-MATES
41	LM5	M5(MM) ETA
42	LM6	M6(MM) MU-MATES
43	LM7	M7(MM) MU
44	LN4	N4(IM) TEMPORARY AVERAGE FLUX
45	LP2	P2(IM,JM) TOTAL FLUX PREVIOUS PASS
46	LP4	NOT USED
47	LRO	R0(IP) INITIAL RADII
50	LR1	R1(IP) CURRENT RADII
51	LR2	R2(IM) RADIAL ZONE NUMBERS -DELTA CALCULATION ONLY
52	LR3	R3(IZ) RADIAL ZONE MODIFIERS (DELTA CALC. ONLY)
53	LR4	R4(IM) RADII-AVERAGE
54	LR5	R5(IM) DELTA-R
55	LS0	S0(IM,JM) TOTAL SOURCE
56	LS4	S4(IMJM,NØMA) TOTAL SOURCE HORIZONTAL (IF ANISO- SCATTERING)
57	LT7	T7(IGM) EV/V7(IGV) USED IN TIME ABSORPTION PROB. S03/V7(IGV) FOR PARAMETRIC EIGENVALUE PROB 0.0 OTHERWISE.

# DØT VARIABLES

\*\*\*\*\* COMMON BLOCK / LØK8 /

LOCATION	VARIABLE	DEFINITION
60	LVO	V0(IM,JM) VOLUME ELEMENTS
61	LV7	V7(IGM) VELOCITIES
62	LW0	W0(MM) WEIGHTS
63	LW1	W1(MM) W0*M7
64	LW2	W2(MM) W0*M5
65	LZ0	Z0(JP) INITIAL AXII
66	LZ1	Z1(JP) CURRENT AXII
67	LZ2	Z2(JM) AXIAL ZONE NUMBERS (DELTA CALCULATION ONLY)
70	LZ3	Z3(JZ) AXIAL ZONE MODIFIERS-DELTA CALCULATION ONLY
71	LZ4	Z4(JM) AXII-AVERAGE
72	LZ5	Z5(JM) DELTA-Z
73	LX0	X0(IM) VOLUME*(TOTAL X-SECT) + T7(IGV)
74	LE0	E0(IGP) TOTAL FIXED SOURCE BY GROUP
75	LE1	E1(IGP) TOTAL FISSION SOURCE BY GROUP
76	LE2	E2(IGP) TOTAL IN-SCATTER BY GROUP
77	LE3	E3(IGP) TOTAL SELF-SCATTER BY GROUP
100	LE4	E4(IGP) TOTAL HORIZONTAL LEAKAGE BY GROUP
101	LE5	E5(IGP) TOTAL ABSORPTIONS BY GROUP
102	LE6	E6(IGP) TOTAL OUT-SCATTER BY GROUP
103	LE7	E7(IGP) TOTAL RIGHT LEAKAGE BY GROUP
104	LF5	F5(IGP) TOTAL VERTICAL LEAKAGE BY GROUP
105	LF6	F6(IGP) TOTAL TOP LEAKAGE BY GROUP
106	LF7	F7(IGP) TOTAL NET LEAKAGE BY GROUP
107	LM8	M8(NACT) MAT. NOS. FOR ACTIVITY PRINT, NOT USED
110	LM9	M9(NACT) X-SECT TABLE POS. FOR ACTIVITY PRINT, NOT USED
111	LABDR	ALBDØR(JM,IGM) RIGHT ALBEDO

# DØT VARIABLES

\*\*\*\*\* CØMMØN BLØCK / LØK8 /

LOCATION	VARIABLE	DEFINITION
112	LABDT	ALBDØT(IM,IGM) TOP ALBEDO
113	LABDB	ALBDØB(IM,IGM) BOTTOM ALBEDO
114	LAST	(LFL) LAST POSITION USED IN BLANK COMMON
115	LENERG	E(IGP) ENERGY BOUNDS
116	LDSCNV	DØSCNV(IGM,IDSOPT) FLUX TO DOSE CONVERSION FACTORS
117	LNGM	NOT USED
120	LRADI	RADI(2*NSCI)RADIAL SECTORS FOR WHICH ANGULAR FLUX IS TO BE PRINTED.
121	LRADJ	RADJ(2*NSCJ)AXIAL SECTORS FOR WHICH ANGULAR FLUX IS TO BE PRINTED.
122	LNIM	NIM(IP) RADIAL MESH FOR WHICH AFLUX IS TO BE PRINTED
123	LNJM	NJM(JP) AXIAL MESH FOR WHICH AFLUX IS TO BE PRINTED
124	LDE	NOT USED
125	LEBAR	NOT USED
126	LNZØUT	NZØUT(IZMØUT) ZONE NUMBERS OF ZONES FOR WHICH VOL. WEIGHTED FLUX BY ZONE CALCULATION IS TO BE PERFORMED

\*\*\*\*\* CØMMØN BLØCK / TITL /

LOCATION	VARIABLE	DEFINITION
0	TITL	UP TO 72 CHARACTER HEADER WHICH IS INPUT AND PRINTED AT TOP OF PAGE AT BEGINNING OF RUN.

\*\*\*\*\* CØMMØN BLØCK / IZFLX /

LOCATION	VARIABLE	DEFINITION
0	IZFLX	0 - NO EFFECT 1 - PRINT VOLUME WEIGHTED FLUX BY ZONE 2 - PUNCH VOLUME WEIGHTED FLUX BY ZONE 3 - BOTH 1 AND 2

# DØT VARIABLES

\*\*\*\*\* CØMMØN BLØCK / IZFLX /

LOCATION	VARIABLE	DEFINITION
1	IZMØUT	0 - PERFORM VOLUME WEIGHTED FLUX CALCULATIONS FOR ALL ZONES. N - PERFORM CALCULATIONS FOR N ZONES SPECIFIED BY 34\$ ARRAY.
2	IZMØ	NUMBER OF ZONES FOR WHICH VOLUME WEIGHTED FLUX CALCULATIONS ARE BEING PERFORMED. ALSO USED AS A ZONE COUNTER.
3	IALL	0 - SIGNIFIES THAT COMPUTATIONS ARE BEING DONE FOR ALL ZONES IZM - SIGNIFIES THAT COMPUTATIONS ARE BEING DONE FOR ZONES SPECIFIED BY *NZØUT* ARRAY.

\*\*\*\*\* CØMMØN BLØCK / DENS /

LOCATION	VARIABLE	DEFINITION
0	IDFM	0 - NO EFFECT 1 - USE DENSITY FACTORS. MULTIPLY CROSS-SECTION BY DENSITY OF MESH INTERVAL BEING CONSIDERED.
1	DENX	TEMPORAY STORAGE FOR A DENSITY FACTOR. IF IDFM=0, DENX ALWAYS IS SET TO 1.0.
2	LDENS	POINTER IN BLANK CØMMØN TO DENSITY FACTOR ARRAY, DENS(IM,JM)

\*\*\*\*\* CØMMØN BLØCK / PT /

LOCATION	VARIABLE	DEFINITION
0	IPT	0 - NO EFFECT 1 - USE POINT SCALE OPTION ON FLUXES
1	IPTSCL	0 - NO EFFECT 1 - CALL POINT SCALE ROUTINE WHEN IPT=1, IPTSCL=1 EVERY THIRD INNER ITERATION
2	IBT5	0 - NO EFFECT 1 - IBT=5, TOP BOUNDARY SOURCE
3	IBR5	0 - NO EFFECT 1 - IBR=5, RIGHT BOUNDARY SOURCE
4	IMJM5	5*IMJM

# DOT VARIABLES

\*\*\*\*\* COMMON BLOCK / LDCPT /

POINTERS TO ARRAYS USED FOR THE POINT SCALE OPTION  
THESE ARRAYS ARE PART OF A BIG ARRAY, CBAN(IMJM,5)  
REFERRED TO IN SUBROUTINES INNER AND WWESOX.

LOCATION	VARIABLE	DEFINITION
0	LPCU	PCU(IM,JM) EQUIVALENT TO CBAN(1,1)
1	LPCR	PCR(IM,JM) EQUIVALENT TO CBAN(1,2)
2	LPCL	PCL(IM,JM) EQUIVALENT TO CBAN(1,3)
3	LPCD	PCD(IM,JM) EQUIVALENT TO CBAN(1,4)

\*\*\*\*\* COMMON BLOCK / DOT2 /

LOCATION	VARIABLE	DEFINITION
0	J	AXIAL INTERVAL POINTER

\*\*\*\*\* COMMON BLOCK / WWEBLK /

LOCATION	VARIABLE	DEFINITION
0	IS3T01	0 - POINT SCALE ROUTINE CONVERGED. 1 - POINT SCALE ROUTINE DID NOT CONVERGE, SET *S3* ARRAY TO 1.0
1	KWE	NUMBER OF ITERATIONS REQUIRED BY POINT SCALE ROUTINE.
2	ERR	CONVERGE ERROR FROM POINT SCALE ROUTINE.

\*\*\*\*\* COMMON BLOCK / DIFFER /

LOCATION	VARIABLE	DEFINITION
0	DIFFER	MAXIMUM FLUX ERROR

# DØT VARIABLES

\*\*\*\*\* LOCAL VARIABLE IDENTIFIER - INP

## SUBROUTINE INP

LOCATION	VARIABLE	DEFINITION
1	IRBC	RIGHT BOUNDARY CONDITION. IRBC = -4 MEANS INPUT SAME SOURCE AT ALL POINTS.
2	ITBC	TOP BOUNDARY CONDITION. ITBC = -4 MEANS INPUT SAME SOURCE AT ALL POINTS.
3	ITMO	OUTER ITERATION MAXIMUM
4	KINDS(3)	BCD CHARACTER STRINGS THAT INDICATED JØBTYPE. \$JØB - NEW JOB, \$RES - RESTART \$ØUT - PROCESS ØUTPUT TAPE(S)

### 2.2.1.2 Data Storage and File Definition

All arrays are assigned to BLANK COMMON. The user must dimension BLANK COMMON large enough to run the problem and must tell the program how many words are contained in BLANK COMMON through the NAMELIST variable LIM1.

The program will determine how large BLANK COMMON needs to be and will print a message indicating the number of words needed.

The logical files used in the DOT/INAP program are:

- NINP - input file, card reader
- NOUT - output file, printer
- NCRI - scratch file for cross sections
- NFLUXI - flux file, normally a scratch file, but the initial flux guess may be input on this file (if IFLX = 5) which would probably be done via tape
- NSCRAT - general purpose scratch file
- NAFT - angular flux file, normally a scratch file, but a tape will need to be mounted if IAFT = 1 or 3
- NSBØ - scratch file for fixed boundary source
- NFLSV - file which restart tape is mounted on
- NPSØ - first collision source tape file. NPSØ and NBSØ may be assigned to the same logical unit as both options are not used at the same time.

The punch file is also used.

### 2.2.1.3 Multiple Subroutine Entry Points

During the conversion of DOT/INAP to the UNIVAC 1108 system, it was found that the argument lists of three subroutines (i.e., INIT, GRINDR, and ØUTER) were longer than permitted so that it was necessary to define multiple entry points for these subroutines. The names of these entry points are given below:

<u>Subroutine</u>	<u>Entry Points</u>
INIT	INIT1
	INIT2
GRINDR	GRINDR2
ØUTER	ØUTER1
	ØUTER2

#### 2.2.1.4 Problem Restart

In order to restart DØT, the total fluxes must be saved on file NFLSV. For a new problem the user must mount a tape on logical unit NFLSV and set the NAMELIST input variable IRES to 1. The problem may be stopped after any group during any outer iteration. For example, if the user desires to halt the problem after the calculations have been done for Group 3 on outer iteration 1, he should make the following NAMELIST entries:

ITTEST = 1,                    IGTEST = 3.

Now when the problem is restarted the same tape should be again mounted on NFLSV. The user must tell the program the number of outer iterations that have been completed and the number of groups that have been completed on the present outer iteration. In the above example the user would enter through NAMELIST:

NGDØNE = 3.

If the problem were restarted during the second outer iteration, the user would have to enter:

NIDØNE = 1.

If, after restarting, the user desires to continue writing the restart tape he must again set IRES = 1. The problem can be halted again by entering new values for ITTEST and IGTEST.

When restarting a problem let the flux input trigger, IFLX, retain its nominal value of zero, and place a "T" in the data deck where the 3\* array should be entered. It should be noted that the program always tries to allocate storage such that the total fluxes will all be kept in central memory, IFØT = 0. If there is not enough room in the bucket to run the problem, then the total fluxes will be stored on a tape or disk file, IFØT = 1. In order for a restart tape to be written, it is necessary that IFØT = 1. Thus, it is necessary that the bucket be small enough to force the total fluxes to be stored on a file. On most problems, the program is required to store total fluxes on a file, but if the user should run a small problem and attempt to write a restart tape, it might not be written if IFØT is not set equal to one.

#### 2.2.1.5 First Collision Source (104 = 6)

One means of reducing errors arising from the discrete ray effect in certain two-dimensional discrete ordinates calculations is to calculate the collided flux using DOT and add this to an uncollided flux determined analytically. The DOT calculation then begins with a first collision source (see Reference 4). This method will not generally be useful for the type of problems encountered in the INAP system, however, the occasion may arise. If a first collision source is desired, the user must mount the first collision source tape prepared by the UNCL<sup>(7)</sup> program on logical unit NPSØ. In addition, it is possible if the user so desires, to save some of the input data, which is common to both DOT UNCL, on a tape or disk file in the UNCL run. This file must then be assigned to logical unit NAFT when making the DOT run. The file contains one logical record as follows:

- (1) The first 1M+1 words contain the radial boundaries (4\* array)
- (2) The next JM+1 words contain the axial boundaries (2\* array)
- (3) The next 1M+JM words contain the zone numbers by mesh interval (8\$ array)
- (4) The last 1ZM words contain the material numbers by zone (9\$ array)

The first IGM records of the first collision source tape contain the first collision sources and the second IGM records contain the uncollided fluxes. These uncollided fluxes are added to the collided flux calculated by DOT.

#### 2.2.1.6 Cross Sections

The cross sections, input by group, for each material, are entered as a two-dimensional array. For each group they are entered in the following format:

<u>Position</u>	<u>Cross Section Type</u>
1	activity
.	activity
:	activity
.	
IHT-2	absorption
IHT-1	fission
IHT	total

If a cross section expansion of order  $L < 0$  is being used and the  $P_0$  cross sections for a particular material are designated material M, then the  $P_1$  cross sections must be material M+1, the  $P_2$  cross sections must be material M+2, and the  $P_L$  cross sections must be material M+L. The cross section sets that are only used in the mixing table do not have to be arranged in this order, but the mixtures and/or input sets that are identified as materials in any problem zone must be so ordered.

Mixtures may be formed through the mixing table arrays. The following table indicates the three types of operations which may be performed.

	<u>10\$</u>	<u>11\$</u>	<u>12*</u>
1.	M	0	X
2.	M	N	X
3.	M	M	0.0

1. Multiply all cross sections in material M by X.
2. Multiply all cross sections in material N by X and add to the corresponding cross sections in material M.
3. Multiply all cross sections in material M by EV, the eigenvalue (concentrate search).

The tables for materials MCR+MTP+1 through MT are initialized to zero, so they do not have to be zeroed with the mixing table; however, if the storage location of an input material is to be reused for a later mixture, it is necessary to first zero the mixture using step #1 with  $x = 0.0$ . It should be noted that, in addition to the mixing table, material densities may be entered using the density factor array (33\*). Therefore, it is not necessary to define a new mixture if only the density is to be changed (for example, a liquid and its vapor) since this may be accomplished with the density factors.

In order to reduce storage requirements the program stores the cross sections on a tape or a disk file by group. That is, the  $i^{\text{th}}$  logical record contains all the cross sections for Group i. But before the program can write this file, all the cross sections must first be read into central core. In some cases, loading all the cross sections into central core is not possible and this file must be written by an auxiliary program on a tape which is mounted on logical unit NCRI for use by DØT.

<u>Position</u>	<u>Cross Section Type</u>
IHT+1	$\sigma_{g+NUS \rightarrow g}$
.	} up-scatter
.	
.	
IHS-1	
IHS	$\sigma_{g+1 \rightarrow g}$
IHS+1	in-scatter
.	$\sigma_{g-1 \rightarrow g}$
.	} down-scatter
.	
.	
ITL	
	$\sigma_{g-NDS \rightarrow g}$

NUS = IHS-IHT-1, number of groups of up-scatter

NDS = ITL-IHS, number of groups of down-scatter.

The parameters IHT, IHS, and ITL completely describe the format of the cross sections. If there are no activities IHT = 3. If there is no up-scatter, IHS = IHT+1. ITL entries must be made for each group; thus the table positions which have no meaning must be filled with zeroes. For example, for Group 1 there are no down-scatters. Hence, NSD zeroes must be entered to fill out the table for Group 1. For Group 2 there is one down-scatter and NDS-1 zeroes must be entered.

Thus, for each material a total of ITL\* IGM entries will be made. The higher order terms of the Legendre exposit are entered as separate materials. They will have the same format as the  $P_0$  cross sections except that table positions\*1 through IHT are not used and should be zeroed. The  $P_L$  cross sections must contain a (2L+1) term. If they do not contain this term when input, it can be included by use of the mixing tables.

Each cross section set is identified by a material number. The cross sections that are read in from cards (14\*) become materials 1 through MCR in the order that they are read in. The cross sections that are read from a library tape become materials MCR+1 through MCR+MTP in the order that they are read in. Any cross section set having a material number M, where  $MCR+MTP < M \leq MT$ , is a mixture and should be defined in the mixing table.

### 2.2.2 Input Description

This section defines and describes the input variables and arrays required by the DØT/INAP program. Section 2.2.1 gives the data deck setup while Section 2.2.2.2 describes the NAMELIST input variables and Section 2.2.2.3 describes the arrays which are processed by the FIDØ Input Routine. This section is only concerned with the DØT/INPUT Program. Section 2.5 contains information on how this program is used in the Engineering Code System and provides special instructions for defining the DØT/INAP problem in a manner consistent with the other programs used by the system.

#### 2.2.2.1 Data Deck

A complete data deck consists of: a title card; NAMELIST Input; and up to eight data blocks containing one or more data arrays. The deck is ordered as follows:

- [illegible]

#### 2.2.2.2 NAMelist Input

NAMELIST variables (NAMELIST name, INPUT)

<u>Variable Name</u>	<u>Other Name in Program</u>	<u>Description</u>
ID	A01	problem identification number - arbitrary
ITH	A02	0 - regular calculation (nominal) 1 - adjoint calculation
ISCT	A03	order of Legendre expansion of scattering

<u>Variable Name</u>	<u>Other Name in Program</u>	<u>Description</u>
ISN	A04	order of quadrature (must be even integer)
IGE		0 - slab geometry 1 - cylindrical geometry (nominal) 2 - spherical geometry
IZM		number of material zones
IM		number of radial mesh intervals
JM		number of axial mesh intervals
I04		problem type (also known as I04 so either name can be used) 0 - fixed volume distributed source (nominal) 1 - homogeneous eigenvalue calculation 2 - time absorption calculation 3 - concentration search calculation 4 - zone thickness calculation 5 - fixed boundary source calculation 6 - use first collision source tape from UNCL program
EV		eigenvalue guess for search calculations (I04 = 2,3, and 4) (nominal = 0.0)
EVM		eigenvalue modifier - the second eigenvalue guess is set equal to $EV \pm EVM$ where the sign of the quantity EVM is taken as positive if the first eigenvalue guess is greater than 1.0. This variable is not used if I04 = 0,1,5, or 6 (nominal = 0.0).
EPS		general convergence criteria, used for the integral inner iteration convergence test and for the lambda and fission density
ILBC	B01	left boundary condition 0 - vacuum (nominal) 1 - reflection 2 - periodic (angular flux leaving boundary re-enters the opposite boundary (left-to-right or top-to-bottom) in the same angle

<u>Variable Name</u>	<u>Other Name in Program</u>	<u>Description</u>
IRBC		<p>right boundary condition</p> <p>0,1,2 - same as for ILBC (nominal = 0)</p> <p>3 - white (isotropic incoming flux, zero net current)</p> <p>4 - boundary source</p> <p>-4 - input boundary source for one interval only - the program will set the values the same for all other intervals along the boundary</p> <p>5 - albedo boundary condition, enter 25* array</p>
ITBC		<p>top boundary condition</p> <p>0,1,2,3,4,-4,5 - same as for IRBC (nominal = 0). If ITBC = 5, albedoes are entered in 26* array</p>
IBBC	B04	<p>bottom boundary condition</p> <p>0,1,2,3,5 - same as for IRBC (nominal = 0). If IBBC = 5, albedoes are entered in 27* array.</p>
IFLX	M07	<p>flux input trigger (how flux guess is to be input)</p> <p>0 - A(G); enter IGM values in 3* array. Input flux is constant in space and is energy dependent. (nominal)</p> <p>1 - N(I,J,G); enter IM+JM values in IGM 3* arrays.</p> <p>2 - A(G) + N(I,J); enter two 3* arrays, IGM entries in first and IM + JM entries in second.</p> <p>3 - A(G) + B(I) + C(J); enter three 3* arrays, IGM entries in first, IM entries in second, and JM entries in third.</p> <p>4 - [B(I) + C(J)]<sub>G</sub>; enter two 3* arrays for each group, IM entries in first, and JM entries in second.</p>

<u>Variable Name</u>	<u>Other Name in Program</u>	<u>Description</u>
IFLX (cont'd)		5 - program expects restart fluxes from tape mounted on unit NFLUX1. Do not enter 3* array. This option should not be confused with the TRW restart capability which enables the user to restart the problem at a particular group.
MØDE	FXT	flux calculation mode 0 - use linear calculations 1 - use linear mode. Recompute negative fluxes with step function equations (nominal) 2 - use step function equations only
MT		total number of materials including mixtures
MS	M01	length of mixture table (10\$, 11\$, 12* arrays) (nominal = 0) MS = 0 means no mixing is to be done.
MCR		number of sets of cross sections (14* array data) to be read from cards (nominal = 0)
MTP		number of cross section sets to be read from library tape mounted on unit NT6. The identification numbers of the sets to be read from tape are entered in the 13\$ array. If both MCR and MTP are zero, the program expects the cross sections to be entered on a group-structured tape mounted on unit NCRI.
IZ		number of radial zones for zone thickness search (nominal = 0)
JZ		number of axial zones for zone thickness search (nominal = 0)
IEVT	S02	type of parametric eigenvalue search 0 - not a parametric eigenvalue search (nominal) 1 - search on $\kappa$ 2 - search on $\alpha$
PEV	S03	parametric eigenvalue for search (nominal = 0)
IGM		position of sigma-total in cross section table

<u>Variable Name</u>	<u>Other Name in Program</u>	<u>Description</u>
IHS		position of in-scatter cross section in table
ITL		cross section table length
XNF	S01	normalization factor, enter zero for no normalization on fixed source problems (nominal = 0)
NACT	M05	number of activities desired (nominal = 0)
IDFS	M06	method of input for distributed fixed source 0,1,2,3,4 - same as for IFLX except that source array is designated 17*. (nominal = 0)
ITII	S04	initial inner iteration maximum per group. This value is used until $ LAMBDA-1.0  < 10.0 * EPS$ (nominal = 20)
ITMØ		outer iteration maximum
ITMI	G07	inner iteration maximum per group (nominal = 20)
ENB	G05	epsilon for neutron balance (not presently used in code) (nominally set to zero)
EPW	G06	epsilon for pointwise flux error, not used if zero. If non-zero the integral inner iteration convergence test is not used. (nominal = 0.0)
XLAL	LAL	epsilon for search. If $ LAMBDA-1.0  < XLAL$ program uses a linear search. Recommended value: XLAL = 0.01 (nominal = 0.01)
XLAH	LAH	upper limit on $(LAMBDA-1.0)$ used in linear search. Recommended value: XLAH = 0.05 (nominal = 0.05)
PØD		parameter oscillation damper. Recommended value: PØD = 0.75 (nominal = 0.75)
DPSA		epsilon for new parameters. Recommended value: EPSA = 0.001 (nominal = 0.001) used in search calculations.
IAFT		angular flux output trigger 0 - no angular flux output desired (nominal) 1 - write binary angular flux tape 2 - print angular fluxes 3 - both 1 and 2

<u>Variable Name</u>	<u>Other Name in Program</u>	<u>Description</u>
IENG	IEØPT	0 - no effect (nominal) 1 - print average energy, and flux per mev 2 - print flux above energy 3 - both 1 and 2
INDS	IDSØPT	0 - no effect (nominal) N - input flux to dose conversion factors for N materials. Print dose and integrated dose. The flux to dose conversion factors are entered in the 29* array.
NPUN	NPUNCH	0 - no effect (nominal) 1 - punch integrated activity
NØGM		not used, nominally blanked out
NSCI	NSCTI	will be ignored if angular fluxes are not printed 0 - print angular flux for all radial intervals (nominal) N - print angular flux for radial intervals which are included in N designated bands (sectors) specified by the 31* array
NSCJ	NSCTJ	will be ignored if angular fluxes are not printed 0 - print angular flux for all axial intervals (nominal) N - print angular flux for axial intervals which are included in N designated bands (sectors) specified by the 32* array. Note: If NSCI and NSCJ are both non-zero, print-out will occur for mesh intervals specified by the intersection of the 31* and 32* arrays.
IPRN	IPRINT	not used
IGIT	IGITER	not used if set to zero (nominal). For groups with group index greater than IGIT, ITII is used as the inner iteration maximum. For

<u>Variable Name</u>	<u>Other Name in Program</u>	<u>Description</u>
IGIT (cont'd)	IGITER (cont'd)	groups with group index less than or equal to IGIT, IIIT is used as the inner iteration maximum.
IIIT	IIITER	used when IGIT is greater than zero (nominal = 0). Inner iteration maximum for groups with index less than or equal to IGIT.
LIMI		number of words in blank common
NFLSV		logical unit to which restart tape is assigned (nominal = 0)
NGDØNE		this variable is used when restarting a problem to indicate the number of groups for which the calculations have been completed on the present outer iteration. (nominal = 0)
NIDØNE		this variable is used when restarting a problem to indicate the number of complete outer iterations which have been performed. (nominal = 0)
IRES		0 - no effect (nominal) 1 - save restart fluxes on tape assigned to logical unit NFLSV
NAFT		logical unit to which angular flux file is assigned. If the angular fluxes are to be saved on tape, this unit must be a tape unit; otherwise, it should be a disk or drum unit (nominal = 11)
MØMENT		has effect only when IAST = 2 and ISCT is non-zero 0 - no effect (nominal) 1 - print flux moments for each energy group
IGTEST		0 - no effect (nominal) N - stop problem after calculations for group N have been completed.
ITTEST		0 - no effect (nominal) N - the outer iteration on which the problem is to be stopped when IGTEST is non-zero

<u>Variable Name</u>	<u>Other Name in Program</u>	<u>Description</u>
IPT		0 - no effect 1 - use point scale option (nominal) when the point scale option is used the problem will run approximately twice as fast as it would if the point scale option were not used. Five (six if ISCT = 0) times IM*JM more words of memory are required, so if core is limited, in some cases the user may find it necessary to sacrifice speed for space.
IDFM		0 - no effect (nominal) 1 - enter density factors by mesh interval in 33* array
IZFLX		0 - no effect (nominal) 1 - print volume weighted flux by zone 2 - punch volume weighted flux by zone 3 - both 1 and 2
IZMOUT		has effect only when IZFLX is non-zero 0 - perform volume weighted flux calculations for all zones (nominal) N - perform calculations for N zones specified by the 34\$ array.

### 2.2.2.3 Data Array Input

All input arrays for DØT are entered in a modified fixed field format which is processed by FIDØ. Each card is separated into six 12-column fields. Each field is broken into 3 subfields (I2, A1, F9.0). Any field which is entirely blank will be ignored with certain exceptions which will be noted. Each array is identified by an integer name and the arrays are grouped into data blocks. The data blocks must be entered in a prescribed order, but arrays within a data block may be entered in any order. The input processor checks the number of entries in each array so that the user must enter exactly this number or an error message will be printed. It is also important to note that any integer values entered into either IN(I) or V(I) must be right-justified. For ease of discussion

refer to the following READ.

```
READ(N, 900) (IN(I), K(I), V(I)), I=1, 6)
900 FORMAT (6(12, A1, F9.0))
```

Contents of K(I)

Meaning

*	signifies start of floating point array. Also acts as terminator of preceding array. The name of this floating point array is IN(I). V(I) is ignored.
\$	same as "*" but signifies start of integer array
blank	enter value V(I) if V(I) is non-blank
+	value to be entered is $V(I) * 10.0 ** IN(I)$
-	value to be entered is $V(I) * 10.0 ** (-IN(I))$
R	enter the value V(I), IN(I) times in succession. The repeat option may not be used in conjunction with exponentiation. That is, the user cannot place an "R" in K(I), leave V(I) blank, and then enter the value to be repeated in the $I + 1^{st}$ field.
I	enter the value V(I) and V(I+1) and IN(I) interpolates in between, for a total of $IN(I)+2$ entries. The end value must be in field I+1, that is, field I+1 will not be ignored even if it is blank. If K(I+1) is also an "I" then V(I+1) will not be entered twice. In this case $IN(I) + IN(I+1) + 3$ entries will be entered. If I is 6 then I+1 will refer to the first field on the next card.

<u>Contents of K(I)</u>	<u>Meaning</u>
S	skip IN(I) words before entering the next value. For this option, V(I) may or may not be blank
Z	enter zero for the next IFIX(V(I)) words in succession. The advantage this option has over the repeat option is that the number of repeats may be larger than 99.
A	the array subscript pointer will be reset to $J = \text{IFIX}(V(I))$ . The next value entered will be in location J.
F	fill the rest of the array with the value V(I)
T	terminator to tell the input processor to stop reading data

In addition, the following options are available:

- (1) Any card with a "C" in column 1 will be treated as a comment card.
- (2) The user may selectively list sections of his input data. To turn the list option on place a card with an "L" in column 1 in the data stream. All cards which follow will be printed out until a card is reached which has an "N" in column 1. (The user may enter words such as LIST and NØLIST, but the first character is the only one looked at.

#### Cross Section

Data Block      Enter if MCR and/or MTP non-zero. Follow by a "T".

<u>Array</u>	<u>Bucket Pointer</u>	<u>Name in Program and Dimensions</u>	
13\$	L13	MTT(MTP)	Library tape identification numbers (positive integers) for cross section sets to be input from a binary library tape assigned to logical unit NT6. These identification numbers must be input in increasing order.

<u>Array</u>	<u>Bucket Pointer</u>	<u>Name in Program and Dimensions</u>	
13\$ (cont'd)	L13 (cont'd)	MTT(MTP) (cont'd)	<p>Format of binary cross section library tape: For each cross section set there are two logical records. The first record contains 12 words. The first three words are not referenced. The fourth word is the identification number. The fifth through twelfth words are a holerith title. The second record contains the cross sections, ITL * IGM words, ordered as follows:</p> <p style="margin-left: 40px;">group 1    positions 1 thru ITL  group 2    positions 1 thru ITL  . . . . .  group IGM positions 1 thru ITL</p> <p>The tape is then written as follows:</p> <p>Identification record for first data set</p> <p>Cross section record for first data set</p> <p>Identification record for second data set</p> <p>Cross section record for second data set, etc.</p> <p>Each identification number on the tape must be greater than that of the preceding data set.</p>
14*	LCØ	CØ(ITL,IGM,MCR)	<p>Cross sections being read from cards. The cross sections for set one are followed by those for set two, etc. Each set (material) is ordered as indicated in the preceding description of a cross section record of a library tape.</p>

Notes: (1) If MCR and MTP are both non-zero, then the cross sections from cards are materials 1 through MCR and those from tape are materials MCR + 1 through MCR + MTP.

Notes (cont'd):

- (2) In some routines in the program the cross section array is known by the name CRX.

Volume Distributed

Fixed Source

Data Block

Enter if I04 = 0. Follow by a "T".

<u>Array</u>	<u>Bucket Pointer</u>	<u>Processing Routine</u>	<u>Array Name</u>
--------------	---------------------------	-------------------------------	-----------------------

17*	LS2	S862	Q0	See description of NAMELIST variable IDFS for dimensions. If more than one 17* array is required, each one must be followed by a "T". So the user will not be confused, it is stated here that there should be one "T" only following the last 17* array.
-----	-----	------	----	---

Fixed

Boundary Source

Data Block

Enter if I04 = 5. Follow by a "T".

<u>Array</u>	<u>Bucket Pointer</u>	<u>Processing Routine</u>	<u>Array Name</u>
--------------	---------------------------	-------------------------------	-----------------------

18*	LCØ	S863	CØ	A boundary source on either the right or top boundary is input to the program by specifying the angle, space, and group dependent boundary condition flux which results from the desired source. The following input rules apply: (1) If both a right boundary source and a top boundary source are being input, the complete input for the right boundary is entered first and followed by the complete input for the top boundary.
-----	-----	------	----	---

(2) The angular fluxes are entered in order by angle, interval, and group, i.e.

group 1	interval 1	all angles
group 1	interval 2	all angles
etc.		

(3) For the top boundary the interval sweep is from left to right

(4) For the right boundary the interval sweep is from bottom to top

(5) For the top boundary a total of  $ISN * (ISN + 4) / 4 * IM * IGM$  entries are required. For each interval and group the

$$ISN * (ISN + 4) / 4$$

angular entries are ordered as they are specified by the quadrature set (7 \* array); however, data is entered only for those angles for which ETA is negative. Initial directions (WEIGHT = 0.0) are included.

\*\*\*\*\* If ITBC = -4, enter values for one interval only. The program will set the values the same for all intervals along the boundary.

(6) For the right boundary a total of  $(ISN * (ISN+4) / 4 + ISN/2) * JM * IGM$  entries are required. For each interval and group the angular entries are ordered as they are specified by the quadrature set; however, data is entered only for those angles for which MU is negative. Initial directions are included.

\*\*\*\*\* IRBC = -4 is analogous to ITBC + -4.

## Initial Flux

Guess

Data Block Enter if IFLX = 0, 1, 2, 3, or 4. Follow by a "T".

<u>Array</u>	<u>Bucket Pointer</u>	<u>Processing Routing</u>	<u>Array Name</u>
3*	LS2	S862	Q0

See descriptions of NAMELIST variables IFLX and IDFS for dimensions. If more than one 3\* array is required, each one must be followed by a "T".

Note: If the user desires to enter all zeros, this can be done by failing to enter a 3\* array even though it is required. Entering a card with a "T" will satisfy the call to the input routine, FIDØ.

## Direction Cosines

Data Block Follow by a "T".

<u>Array</u>	<u>Bucket Pointer</u>	<u>Name in Program and Dimensions</u>
7*	LM7	M7(MM)
	LM5	M5(MM)

MM = (ISN \* (ISN+4))/2  
Direction cosines,  $\mu$  and n. The  $\mu$ 's precede the n's.

## Quadrature Weights

Data Block Follow by a "T".

<u>Array</u>	<u>Bucket Pointer</u>	<u>Name in Program and Dimensions</u>
6*	LW0	W0(MM)

MM defined in preceding data block

## Rest of Data

Data Block Follow by a "T"

<u>Array</u>	<u>Bucket Pointer</u>	<u>Name in Program and Dimensions</u>
1*	LK7	K7(IGM)

Fission spectrum. The sum of the IGM values of the 1\* array should equal 1.0 for  $K_{eff}$  or search calculations (104=1,2,3,4). If 104=0,5, or 6 and fissionable materials are in regions, then the 1\* values may be input as 0.0 to suppress calculation of new fission source distributions on outer iterations.

<u>Array</u>	<u>Bucket Pointer</u>	<u>Name in Program and Dimensions</u>	
4*	LRO	RO(IM+1)	Radial mesh interval boundaries.
2*	LZO	ZO(JM+1)	Axial mesh interval boundaries.
8\$	LMO	MO(IM,JM)	Zone number by mesh interval. Data are entered starting at the lower left mesh interval of the geometry and entered for all X or R mesh intervals for the first Y, Z, or $\theta$ mesh column, all mesh intervals for the second Y, Z, or $\theta$ mesh column, etc., i.e.: MO(1,1), MO(2,1)..... MO(IM,1), MO(1,2), MO(2,2), ..... MO(IM,2)..... MO(1,JM), ..... MO(IM,JM)
9\$	LM2	M2(IZM)	Material numbers by zone. A negative number indicates that the zone contains an anisotropic material. In the mixing tables or cross-section input order, the mixture cross-sections in the number sequence following the negative number contain the $P_n$ tables for the mixture in the zone. For example, if material 6 is anisotropic $P_3$ the enter a "-6" in the 9\$ array and put the $P_1$ , $P_2$ , and $P_3$ tables in mixtures 7, 8, and 9.
5*	LV7	V7(IGM)	Representative velocities by group. Velocities must be non-zero and are required input only for a time absorption calculation (104 #2) enter velocities as 1.0's.
10\$	LI0	IO(MS)	Mixture material numbers in mixing table. Enter if MS >0.
11\$	LI1	II(MS)	Component material numbers of mixtures in mixing table. Enter if MS >0.

<u>Array</u>	<u>Bucket Pointer</u>	<u>Name in Program and Dimensions</u>	
12*	LI2	I2(MS)	Mixture table densities. Enter if MS > 0
21\$	LR2	R2(IM)	Radial search zone numbers. Enter if I04=4.
22*	LR3	R3(IZ)	Radial search zone modifiers. Enter I04=4.
23\$	LZ2	Z2(JM)	Axial search zone numbers. Enter if I04=4.
24*	LZ3	Z3(JZ)	Axial search zone modifiers. Enter if I04=4.
25*	LABDR	ALBDØR(JM, IGM)	Right boundary albedo data. Enter if IRBC=5. Enter by group, i.e., group 1, all intervals; ..... group IGM, all intervals.
26*	LABDT	ALBDØT(IM, IGM)	Top boundary albedo data. Enter if ITBC=5. Enter by group.
27*	LABDB	ALBDØB(IM, IGM)	Bottom boundary albedo data. Enter if IBBC=5. Enter by group.
28*	LENERG	E(IGM+1)	Energy bounds. Needed if IENG ≠ 0 and/or IZFLX ≠ 0
29*	LDSCNV	DØSCNV(IGM, INDS)	Group overaged response functions, later INDS sets by group.
31*	LRADI	RADI(2*NSCI)	Boundaries of each of NSCI sectors in radial direction for which angular printout is desired. Must be entered in increasing order and as follows: $R_{low}^1, R_{up}^1, R_{low}^2, R_{up}^2, \dots$ $R_{low}^{NSCI}, R_{up}^{NSCI}$ Angular flux printout will occur for intervals included in these sectors. Enter if NSCI > 0.

<u>Array</u>	<u>Bucket Pointer</u>	<u>Name in Program and Dimensions</u>	
32*	LRADJ	RADJ(2*NSCJ)	<p>Same as 31* array but for axial direction. Enter if NSC1 &gt;0.</p> <p>Note: The 31* and 32* arrays have meaning only if IAFI <math>\geq</math> 2.</p> <p>If both a 31* and a 32* array are entered, printout will occur for those intervals determined by the intersection of the 31* and 32* arrays.</p>
33*	LDENS	DENS(IM,JM)	<p>Density factors. Enter if IDFM &gt;0.</p> <p>Enter in the following order:</p> <p>Axial interval 1: radial intervals 1-IM</p> <p>Axial interval 2: radial intervals 1-IM.</p> <p>Axial interval JM; radial intervals 1-IM</p> <p>When density factors are used, the cross section is multiplied by the density factor in the interval being considered each time cross-sections are referenced in the calculations.</p>
34\$	LNZOUT	NZOUT(IZMOUT)	<p>Zone numbers for which zone weighted flux calculations are to be performed. Enter if IZMOUT &gt;0. Zone numbers do not have to be entered in increasing order and any redundant specifications will be ignored.</p>

### 2.2.3 Output Description

This section presents a brief description of the output from DDT/INAP. The output data which is unique to DDT/INAP is further described by providing the algorithms with which they are computed. Also described are the restart and angular flux tapes which may be prepared on option.

#### Input Data Summary and Edit

- (1) Message indicating processor time that problem starts.
- (2) Title card at top of page.
- (3) NAMELIST parameters with definitions.
- (4) Messages indicating amount of BLANK COMMON needed for problem.
- (5) After each data array is read in, the array name and the number of entries read is printed. The terminator "T" is also printed. The volume distributed fixed source, if entered, is printed by group.
- (6) Two-dimensional map showing zone number by mesh interval. The mesh interval with the minimum radius and height is at the lower left corner.
- (7) Two-dimensional map showing material number in each mesh interval.
- (8) Message indicating processor time when input link is exited.
- (9) Angular quadrature constants
  - (a) angle number
  - (b) WT, weights (7\*)
  - (c) ETA, direction cosines with respect to Y, Z, or  $\theta$  axis (6\*)
  - (d) MU, direction cosines with respect to X or R axis (6\*)
  - (e) MU\*WT
  - (f) ETA\*WT
  - (g) M3, a term used in the geometric angular redistribution
  - (h) M4, the MU mates for horizontal boundary reflection
  - (i) M6, the MU mates for vertical boundary reflection
- (10) If ISCT>0, the constants used by the moment operators in the anisotropic in-scatter integral are printed.
- (11) Cross-sections by group. Print-out takes place after mixing is done.
- (12) Density factors by mesh interval (33\*), if IDFM=1.
- (13) If I04=0 and XNF>0.0, the distributed fixed source values are normalized so that the total integrated fixed source equals the normalization factor, XNF. The normalized values are printed by group.

- (14) If  $IO4=5$ , the boundary source is printed (18\*).
- (15) Important one-dimensional arrays:
  - (a) Mixing table mixture numbers (10\$)
  - (b) Mixing table component numbers (11\$)
  - (c) Mixing table densities (12\*)
  - (d) Radial interval boundaries (4\*)
  - (e) Radial interval midpoints
  - (f) Axial interval boundaries (2\*)
  - (g) Axial interval midpoints
  - (h) Material number by zone (9\$)
  - (i) Fission spectrum (1\*)
  - (j) Velocities (5\*)
  - (k) If  $IO4=4$ , the radial search zone numbers (21\$)
  - (l) If  $IO4=4$ , the radial zone modifiers (22\*)
  - (m) If  $IO4=4$ , the axial search zone numbers (23\$)
  - (n) If  $IO4=4$ , the axial zone modifiers (24\*)
- (16) Boundary albedoes by group and angle
  - (a) If  $IRBC=5$ , the right boundary albedoes
  - (b) If  $ITBC=5$ , the top boundary albedoes
  - (c) If  $IBBC=5$ , the bottom boundary albedoes
- (17) Message indicating processor time when initialization link is exited.

#### Iteration Output

- (1) Monitor print-out, printed initially and at the end of each outer iteration
  - (a) FLUX, logical unit that total fluxes are written on
  - (b) LC, outer iteration number
  - (c) II, total number of inner iterations done
  - (d) NB, neutron balance
  - (e) EQS, if a search, the slope,  $dEV/dLA$
  - (f) EV, eigenvalue
  - (g) LA, ratio of sources
- (2) Message at end of each inner iteration indicating group number, inner iteration number, number of nonconverged points, maximum flux error, and mesh interval where maximum flux error occurred.

- (3) If IPT=1, a message after each call to the point scale routine, WWESØL, indicating the number of iterations if required for convergence and the maximum error.
- (4) Message after calculations for each group are finished indicating processor time.
- (5) If IAF=2 or 3 the angular fluxes are printed on the last outer iteration. Each array is preceded by a title giving the group and axial interval. A FLAG= -1.0 in the title means that the angle numbers correspond to the same angle numbers in the  $S_n$  constants. A FLAG= +1.0 in the title means that the angle number, N, corresponds to angle N+MM/2 in the  $S_n$  constants where MM is the total number of angles.

#### Final Output

- (1) Balance tables including the following for each group:
  - (a) FIXED SØ, the distributed or boundary source
  - (b) FISSION SØ, the fission source
  - (c) IN-SCATTER, the rate of scattering into the group
  - (d) SELF-SCATTER, the within group scattering
  - (e) HZ-LEAKAGE, the right boundary leakage minus the left boundary leakage
  - (f) ABSORPTIONS, the absorption rate
  - (g) OUT-SCATTER, the rate of scattering from the group
  - (h) RFLEAKAGE, the right boundary leakage
  - (i) VT-LEAKAGE, the top boundary leakage minus the bottom boundary leakage
  - (j) TOP-LEAKAGE, the top boundary leakage
  - (k) NET-LEAKAGE, the horizontal plus vertical leakage
  - (l) BALANCE, source rate divided by loss rate
- (2) The final values (in the case of search calculations) for the radial and axial interval boundaries and midpoints.
- (3) The scalar (total) fluxes by group for each mesh interval.
- (4) The group integrated fluxes by mesh interval.
- (5) Fission Edit. The fission neutron source rate per unit volume is printed by mesh interval.

- (6) Average energy, if IENG=1 or 3. Computed for each mesh interval as follows:

AVGE - flux weighted average energy  
 FLUX - scalar flux by group and mesh interval  
 EBAR - average energy of each group

$$\text{For } I=1, \text{IMJM}$$

$$\text{AVGE}(I) = \frac{\sum_{IIG=1}^{IGM} \text{FLUX}(I, IIG) * \text{EBAR}(IIG)}{\sum_{IIG=1}^{IGM} \text{FLUX}(I, IIG)}$$

- (7) Sum of fluxes above energy, if IENG=2 or 3. Integrated flux sum above each energy level. Computed for each mesh interval as follows:

FLXAE - flux above energy  
 FLUX - scalar flux by group and mesh interval

For I=1, IMJM and IIG=1, IGM

$$\text{FLXAE}(I, IIG) = \sum_{IG=1}^{IIG} \text{FLUX}(I, IG)$$

- (8) Flux per MeV for each group and mesh interval, if IENG=1 or 3. Computed as follows:

FLXE - flux per MeV  
 E - energy bounds on each group  
 FLUX - scalar flux by group and mesh interval

For I=1, IMJM and IIG=1, IGM

$$\text{FLXE}(I, IIG) = \text{FLUX}(I, IIG) / (E(IIG+1) - E(IIG))$$

- (9) Dose by group and mesh interval and total dose, if INDS>0. Computation done for each set of flux to dose conversion factors as follows:

DØS - dose by group and interval  
 TØTDØS - total dose  
 FLUX - scalar flux  
 DØSCNV - flux to dose conversion factors

For I=1, IMJM and IIG=1, IGM

$$\text{DØS}(I, IIG) = \text{FLUX}(I, IIG) * \text{DØSCNV}(IIG)$$

$$\text{TØTDØS}(I) = \sum_{IIG=1}^{IGM} \text{DØS}(I, IIG)$$

(10) Flux Moments. If IAF=2 and ISCT  $\neq$  0 and MØMENT  $\neq$  0 the moments of the flux are printed by group, moment number, and space point. A flux moment is the product of angular flux, moment operator, and angle weight summed over angle. Usually the first moment is the radial current and the second is the axial current.

(11) Activity by mesh interval, if NACT>0. Computed for each activity cross-section as follows:

ACT - activity  
 FLUX - scalar flux  
 MNBYIN - material number by interval  
 CRX - cross sections

For I=1,IMJM and NA=1,NACT

$$ACT(I,NA) = \sum_{IIG=1}^{IGM} CRX(NA,IIG,MAT)*FLUX(I,IIG)$$

where MAT = MNBYIN(I)

If IDFM=1, the density factor interval I will be multiplied by the cross-section.

If NPUN=1, the activities are punched in "FIDØ" format.

(12) Volume weighted flux by zone, if IZFLX>0. Printed if IZFLX=1 or 3, punched if IZFLX=2 or 3. Computed for each zone and group as follows:

FLUXZ - volume weighted flux by zone  
 FLUX - scalar flux  
 VØL - volume of each mesh interval

For IZ=1,IZM and IIG=1,IGM

$$FLUXZ(IIG,IZ) = \frac{\sum_{I=1}^{NINT} VØL(I)*FLUX(I,IIG)}{\sum_{I=1}^{NINT} VØL(I)}$$

where NINT represents the mesh intervals which make up zone IZ.

### 2.2.3.1 Restart Tape (If IRES=1)

The restart tape is written in the binary mode. For each outer iteration a file is written. The first IGM logical records contain the total fluxes and associated information, one record for each group. Each of these records is constructed as follows:

- (1) The first  $IM*JM$  words in the record contain the scalar flux in the order (1,1), (2,1) ....., (IM,1), (1,2), (2,2), ....., (IM,2), ....., (IM,JM).
- (2) The next  $IM*JM*(ISCT*(ISCT+3))/2$  words contain the flux moments. The terms are arranged by interval in the same order as the scalar fluxes for each moment operator. If  $ISCT=0$ , then a single meaningless word is written.
- (3) The next  $MM*JM$  words contain the outgoing angular fluxes at the left and right boundaries. The angular fluxes are arranged by angle and axial interval in the order (1,1), ....., (MM,1), (1,2), ....., (MM,2), ....., (MM,JM). The relationship between angle number and direction is given by the  $S_n$  constants table in the output. Those fluxes, for an axial interval  $J$  and an angle  $M$ , for which  $MU(M)$  is negative, are for the left boundary, and those for which  $MU(M)$  is positive are for the right boundary.
- (4) The next  $MM*IM$  words contain the outgoing angular fluxes at the top and bottom boundaries. The order of the fluxes is similar to that in the preceding item 3. In a similar manner the fluxes, for a radial interval  $I$  and an angle  $M$ , for which  $ETA(M)$  is negative are for the bottom boundary, and those for which  $ETA(M)$  is positive are for the top boundary.
- (5) The following five words are last on the record:
  - VHL, horizontal leakage
  - VRL, right leakage
  - VVL, vertical leakage
  - VTL, top leakage
  - VNL, net leakage

Then a record is written containing the following:

- (1) The first  $IM*JM$  words contain the fissions.
- (2) At the end of the record two more words are written:

ALA, Lambda-ratio of sources  
UP2, absolute value of the up-scatter error

An end-of-file is written after this final record.

#### 2.2.3.2 Angular Flux Tape (If IAFT = 1 or 3)

There are  $2*JM*IGM+2$  records written in the following order.

Record 1: (TITL(I), I=1,12)

where TITL - holerith title which was input to the  
program

Record 2: IM, JM, ISN, NØANG, (WEIGHT(I), ETA(I), I=1, NØANG)

where IM - number of radial mesh intervals

JM - number of axial mesh intervals

ISN - order of SN quadrature

NØANG -  $(ISN*(ISN+4))/4$

WEIGHT - quadrature weights

ETA - angular quadrature direction cosines

Records 3→ $2*JM+2$ : angular fluxes for group 1

Records  $2*JM+3$ → $4*JM+2$ : angular fluxes for group 2

Records  $2*JM*(IGM-1)+3$ → $2*JM*IGM+2$ : angular fluxes for group IGM

As can be noted there are  $2*JM$  records for each group. Each record is  $IM*T15$  words long where T15 is the number of angles in the upward or downward direction. The angles are arranged in the same order as the quadrature constants. The first angle for a downward directed set corresponds to the first angle in the quadrature; the first angle in an upward directed set corresponds to angle T15+1 in the quadrature. The records are arranged in the following order:

- (1) Angular flux for J=JM, downward angles
- (2) Angular flux for J=JM-1, downward angles
- (JM) Angular flux for J=1, downward angles
- (JM+1) Angular flux for J=1, upward angles
- (JM+2) Angular flux for J=2, upward angles
- (2\*JM) Angular flux for J=JM, upward angles

## 2.3 Activation and Decay Chain Module

It is the purpose of this module to compute the activation gamma ray source strength in each material zone for which an average neutron flux is provided by DØT/INAP. The neutron flux is used along with the specified isotopic compositions of the material zones to compute the production rates of the radioactive isotopes resulting from various neutron induced reactions. With this information and a specified, time dependent "power level" describing the time variation of the neutron sources the decay chain calculations are performed and the activation gamma ray source strengths are determined. The NAP<sup>(8)</sup> program has been selected to perform these functions in the Engineering System.

### 2.3.1 Operating Instructions

The INAP version of the NAP program is changed very little from that reported in Reference 8. Therefore, a detailed description of the program is not provided since it would only be redundant. Reference 8 provides a complete users manual for NAP so that the information provided herein serves to document the changes which were made to integrate NAP into the INAP Engineering System. Since several changes were made in the required input, Section 2.3.2 provides a complete description of the NAP/INAP input. Section 2.3.3 describes the minor differences between the NAP and NAP/INAP output. The following paragraphs will provide operating instructions and a description of the modifications which were incorporated into NAP.

The principal modification was to deactivate the neutron transport calculation performed by NAP since this is now performed by DØT. The average neutron flux for each region is prepared by DØT for input to NAP in the FLXIN array. In addition, the neutron energy group structure and the geometrical boundaries and volumes of the regions over which the neutron flux has been averaged are provided by DØT for input to NAP. A flag, IQXT, has been added to the INAP version to suppress a great deal of the non-essential output and several variables and arrays which were required to perform the neutron transport calculation have been eliminated.

Since NAP automatically assumes the energy of the first neutron group to be 21.17 MeV, reaction cross sections may be averaged over a much wider range than desired and reactions with threshold energies greater than the greatest neutron energy may be introduced. This has been eliminated in the INAP version by introducing a "dummy" energy group whose energy range extends from the upper energy of the first neutron group of the DOT calculation up to 21.17 MeV. The flux in this group is set to zero automatically by NAP. No inconsistency will result if the upper energy of the first DOT group is 21.17 MeV.

It was also found to be more convenient to input several variables required only by KAPV into NAP to eliminate the need to insert additional data cards into the KAPV input deck prepared by NAP. These variables are defined in Section 2.4.2 with the remainder of the KAPV input.

Correct operation of the NAP program requires placement of the NAP Cross Section Library tape on FØRTRAN tape unit 8 and the NAP Gamma Radiation Library tape on FØRTRAN tape unit 10. FØRTRAN logical file 1 is used to store any cross section data submitted by the program user. FØRTRAN logical file 2 is used for temporary storage during program operation. FØRTRAN logical file 20 is used to store dose and dose rate calculational quantities to be output for use in the KAPV part of the INAP engineering system. The nominal FØRTRAN logical files 5, 6, and 7 are used for input, output, and punch.

### 2.3.2 Input Description

This section defines the input variables and specifies the input format for each input card necessary in using the engineering INAP version of the NAP program. Except for the first input card, which is the problem title and contains alphabetical and numerical characters, all input data to the NAP program are integer numbers or floating point numbers. Those pieces of data which are output by the DOT code in the INAP system are noted.

Card Type 1, format 12A6; Problem Title. This card is simply a title card and may contain any 72 alphanumeric characters. The title will appear at the top of each page of output data.

Card Type 2, format 10I5; NØREG, NØBG. (Output by DØT in INAP system).

NØREG is the total number of spatial regions in the problem and must be less than 21.

NØBG is the number of neutron energy groups used in the specification of the neutron flux. NØBG must be less than 44.

Card Type 3, format 6E12.5; ELIM(I). (Output by DØT in INAP system).

ELIM(I) is the lower energy limit of neutron energy group I in units of electron-volts. Here I is a running index such that  $I=1,2,3, \dots, NØBG+1$ , where NØBG is the total number of neutron energy groups entered on Card Type 2. The values of ELIM(I) are specified six values per card in order of decreasing neutron energy. The upper energy limit of the first neutron energy group is not specified but is programmed to be 21.17 MeV, and the neutron flux in this "dummy" group is set to 0. The total number of energy limits entered is thus equal to NØBG. As many as seven cards of this type may be required.

Card Type 4, format 6E12.5; RMIN(J), RMAX(J), ZMIN(J), ZMAX(J), VØL(J), (Output by DØT in INAP system).

RMIN(J) is the minimum radius of region J. Similarly, RMAX(J), ZMIN(J), ZMAX(J) and VØL(J) are the maximum radius, minimum axial distance, maximum axial direction and volume of region J.

Card Type 5, format 6E12.5; FLXIN(I). (Output by DØT in INAP system).

FLXIN(I) specifies the neutron flux using the energy group structure previously entered on Card Type 3. Here I is a running index such that  $I=2,3,4, \dots, NØBG+1$ , where NØBG is the number of neutron energy groups entered on Card Type 2. Thus, FLXIN(I) is the incident neutron flux in energy group I, except in the first group where it is set to 0. The values of the FLXIN array are listed in order of decreasing energy (increasing group number) and should have units of neutrons/cm<sup>2</sup>-sec.

Cards 4 and 5 are repeated for all regions, J;  $J=1,2,3, \dots, NØREG$ .

Card Type 6 format 15, IWT.

IWT is a control for the neutron flux spectrum weighting given to the reaction cross sections for NOBG less than 43. If IWT=0, a fission flux spectrum is used to weight the cross sections above 183 keV and a 1/E flux spectrum below 183 keV; IWT=1, a 1/E flux spectrum; IWT=2, a constant flux per unit energy spectrum.

Card Type 7, format 10I5; IQXT.

IQXT is a print option. For  $IQXT \geq 1$ , the decay chains and associated quantities will be suppressed.

Card Type 8, format 10I5; NØGG.

NØGG is the number of gamma ray energy groups to be used in the description of the gamma ray energy spectrum. NØGG must be less than 21.

Card Type 9, format 6E12.5; EGG(1).

EGG(1) are floating point numbers which are the gamma ray energy group limites desired in the NAP computation. Here 1 is a running index such that  $1 = 1, 2, 3, \dots, NØGG+1$ , where NØGG is the number of gamma ray energy trroups entered on Card Type 7. The EGG(1) are expressed in MeV and must be listed in order of decreasing value, six values to a card. Unlike the specification of the neutron energy group limits, the uppermost gamma ray energy group limit must be specified. Thus, EGG(1) is the upper energy limit of the first gamma ray energy group, EGG(2) is the lower energy limit of the first gamma ray energy group, EGG(3) is the lower energy limit of the second gamma ray energy group, etc. All photons of energy above the largest energy limit or below the smallest energy limit are ignored. Up to four cards of this type may be required.

Card Type 10, format E12.5, 16; TFAC, NØNV.

TFAC is a floating point number which specifies the thermal averaging parameter. All group 43 neutron reaction cross sections are multiplied by TFAC. Thus, TFAC is that factor such that multiplication of the 2200 m/sec cross section value of a  $1/v$  cross section by TFAC yields the effective thermal cross section. For example, if the thermal neutron flux is assumed to have a Maxwelllian velocity distribution with a most probable velocity of 2200 m/sec, then TFAC is the ratio of the most probable velocity to the average velocity and should be entered as  $1/1.128 = 0.8862$ .

NØNV is an integer equal to the number of isotopes in the problem (in all spatial regions for which gamma ray source strengths are desired) whose thermal cross sections are not  $1/v$ . The maximum value of NØNV is ten.

Card Type 11, format 3(2I6, E12.5); NZ(I), NA(I), VFAC(I). Must be submitted if and only if NONV is greater than zero.

NZ(I) is an integer equal to the atomic number of the Ith isotope having a non-1/v thermal cross section. Here I is a running index such that  $I = 1, 2, \dots, \text{NONV}$ .

NA(I) is an integer equal to the atomic mass number of the Ith isotope having a non-1/v thermal cross section.

VFAC(I) is a floating point number equal to the non-1/v factor for the Ith isotope having a non-1/v thermal cross section. In computing neutron reaction rates for isotopes originally present in the problem, the NAP program searches the NZ, NA table provided by cards of tape 10. If both the atomic number and the mass number of the isotope under consideration are found in the table, the thermal (Cross Section Library neutron energy group 43) cross section is multiplied by both TFAC and VFAC(I) to obtain an effective thermal cross section for use in computing the reaction rate. Three sets of NZ, NA, and VFAC are permitted in the order (NZ(1), NA(1), VFAC(1), NZ(2), NA(2), VFAC(2), NZ(3), NA(3), VFAC(3). Since NONV must be equal to or less than ten, a maximum of four cards is permitted, the last card having only one set of values.

Card Type 12, format 1I6; NOPER

NOPER is an integer equal to the total number of time periods in which the power level is constant. NOPER is limited to a value of 50 or less.

Card Type 13, format 6E12.5; POW(I).

POW(I) is a floating point number which gives the value of the power level  $P(t)$  during the Ith time period. Here I is a running index such that  $I = 1, 2, \dots, \text{NOPER}$ . It is essential that the product of POW, FLXIN, and the neutron cross sections, whether taken from the NAP Cross Section Library or supplied by the user, has dimensions of neutrons/sec. The number of values of POW(I) submitted, six to a card, must be equal to the value of NOPER. A value of zero entered for any POW(I) implies that there is no neutron flux during the Ith time period.

Card Type 14, format 6E12.5; TI(I).

TI(I) is a floating point number equal to the duration in hours, of the Ith time period. Here I is a running index such that  $I = 1, 2, \dots, \text{NOPER}$ . The power level POW(I) is constant throughout the time period of length TI(I). There must be NOPER values of TI(I) given, six per card.

Card Type 15, format 12I6, NINT(I).

NINT(I) is an integer equal to the number of equal time intervals contained in the time period of length TI(I). Again I is a running index such that  $I = 1, 2, \dots, \text{NOPER}$ . Thus, the Ith time period of length TI(I), during which the power level is constant at the value POW(I), is divided into NINT(I) time intervals, each of length  $\text{TI(I)}/\text{NINT(I)}$ . The radioisotopic atom densities, gamma ray source strengths, and gamma ray dose rates are computed at the end of each time interval. There must be NOPER values of NINT(I) given, twelve per card. The total number of time intervals used in all the time periods is limited to 200. That is, the sum of the values of all the NINT(I) must be equal to or less than 200.

Card Type 16, format 15; NTIME.

NTIME is the dose and dose rate calculational option to be passed on to KAPV in the INAP system and, when specified, is the number of time intervals or times, respectively, for which the dose or dose rates are desired. For NTIME >0 a dose rate calculation is to be made by KAPV and the appropriate gamma source rates will be output from NAP. For NTIME <0 a dose calculation is to be performed by KAPV and the time integrated gamma source strength will be output by NAP. For NTIME =0 no KAPV data will be output.

Card Type 17, format 6E12.5; TIME(I)

This card is required if NTIME  $\neq 0$ . For NTIME >0, the data to be input are the times at which the dose rate calculation of KAPV is to be computed. For NTIME <0, the data to be input are the end times of intervals at which the dose calculation by KAPV is to be performed. For either case there are to be NTIME entries to a maximum of 200.

Card Type 18, format 16; NX.

NX is an integer which specifies the number of neutron reaction cross section sets supplied by the program user, to be used in preference to the NAP Cross Section Library. Each reaction type for each isotope is counted

as a single set. If no cross sections are supplied, NX should be entered as zero.

Card Type 19, format 10E8.1; X(M).

X(M), M = 1, 2, ..., 50, is an array of floating point numbers, ten per card, giving the microscopic cross section set supplied by the program user. Five cards of this type constitutes a single cross section set. These cards must not be submitted if NX is zero.

X(1) = atomic number (Z) of isotope described by this set of cross sections.

X(2) = mass number (A) of isotope.

X(3) = fractional abundance of naturally occurring isotope.

X(4) = a number describing the type of cross section given. Acceptable values of X(4), and their meanings, are given in Table 2.3-1.

TABLE 2.3-1  
IDENTIFICATION OF CROSS SECTION TYPE

X(4)	Type of Reaction	Product Nucleus	
		Ground State	Isomeric State
1	(n, $\gamma$ )	x	
2	(n,p)	x	
3	(n, $\alpha$ )	x	
4	(n,2n)	x	
11	(n, $\gamma$ )		x
12	(n,p)		x
13	(n, $\alpha$ )		x
14	(n,2n)		x
100	(n, $\gamma$ ) resolved resonance	x	
200	(n, $\gamma$ ) resolved resonance		x

X(5) = microscopic potential scattering cross section  
(barns).

If X(4) is less than 100,

X(6) = cross section (barns) for neutron energy group 1.

X(7) = cross section (barns) for neutron energy group 2.

. . .  
. . .

X(48) = cross section (barns) for neutron energy group 43.

If X(4) is 100 or 200,

X(6) = neutron resonance energy (eV) for first resonance.

X(7) = resonance statistical factor g for first resonance.

X(8) = resonance capture width (eV) for first resonance.

X(9) = resonance neutron width (eV) for first resonance.

X(10) = resonance parasitic width (eV) for first resonance.

X(11) = neutron resonance energy (eV) for second resonance.

. . .  
. . .

X(50) = resonance parasitic width (eV) for ninth resonance.

If X(4) is less than 15, the NAP program assumes that the cross section set is supplied, using a 43-group neutron energy structure, in the order of decreasing energy. The cross section for group 43 is assumed to be a 2200 m/sec value, i.e., it is multiplied by TFAC and by VFAC, if appropriate, in computing the reaction rate. Five cards must be supplied for each cross section type given. Additional cross section sets are placed in order of increasing Z, increasing A, and increasing value of X(4). For example, cross section sets for  $^{70}_{30}\text{Zn}$  must precede those for  $^{69}_{31}\text{Ga}$ .

Card Type 20, format 1015; ISUM(IR), LSØ(IR), MSØ(IR), IST(IR).  
(Input to be passed onto KAPV for INAP system). (IR is region index).

These quantities are described in Section 2.4.2 on the KAPV input as are quantities on the following 2 card types. The options associated with these cards are the same as for KAPV and only the format of the cards changed from that of KAPV.

Card Type 21, format 10I5; NSØ(I), I = 1, 2, 3, ... LSØ(IR).

Card Type 22, format 6E12.5; PHI(J,I), I = 1, 2, 3, ... LSØ(IR),  
J = 1, 2, 3, ... NSØ(I).

Card Type 23, format 1I2, 4E12.5; ISØR, TEMP, RD.

This card type and the following are grouped together in order of increasing region number. There must be NØREG cards of this type.

ISØR is an integer specifying the number of isotopic or elemental atom densities to be specified as initially present in the region. ISØR must not be greater than 20. If ISØR is zero, the region is not considered in the computation of gamma ray source strengths.

TEMP is a floating point number giving the temperature (degrees Fahrenheit) of the region, and is used only in effective resonance integral calculations.

RD is a floating point number giving the distance (cm) from the center of the region to the position where gamma ray dose rate and dose information is desired. If RD is entered as zero, no such information will be obtained, and the NAP program will advance to the next region, after computing the gamma ray source strengths. A value of zero is recommended unless a gamma ray shielding calculation by KAPV is not to be performed.

Card Type 24, format 3 (2I3, 16, E12.5); IZ(I), IA(I), IKEY(I),  
DEN(I).

IZ(I) is an integer giving the atomic number of the Ith isotope initially present in the region. On this type card, I is a running index such that I = 1, 2, ..., ISØR.

IA(I) is an integer equal to the atomic mass number of the Ith isotope initially present in the region. If IA(I) is entered as zero, the NAP program assumes that the element specified by IZ(I) is present in its naturally occurring isotopic composition, provided that composition is available in either the NAP Cross Section Library or in the Cross Section sets supplied by the program user.

IKEY(I) is an integer which controls the origin of all neutron reaction cross sections for the Ith isotope or element according to the following scheme:

IKEY = 0: Cross sections will be calculated if not found in the NAP Cross Section Library.

IKEY = 1: Cross sections will be set equal to zero if not found in the library.

IKEY = 2: Cross sections will be calculated even if found in the library.

IKEY = 3: Cross sections are supplied (Card Type 20) by the user. If not found in the supplied data, they will be calculated.

DEN(I) is a floating point number giving the isotopic (or elemental) atom density ( $10^{24}$  atoms/cc) of the Ith isotope.

Cards of types 20 through 24 must be supplied as appropriate for each region.

Cards 1 through 24 are supplied as appropriate for each case desired. Termination of the NAP calculations is made by a card with the word LAST starting in column 1 of the card at the end of all data.

### 2.3.3 Output Description

With the exception of the data punched out in KAPV input format the NAP output is unaltered from that described in Reference 8. The card images of the punched data are printed for the users reference. See Section 2.5 for a list of these variables.

## 2.4 Gamma Ray Shielding Module

The purpose of this module is to determine the gamma ray doses or dose rates at specified locations in complex engineering structures from the gamma ray source strengths in specified source regions provided by the activation and Decay Chain Module. The dose rate and/or cumulative dose will usually be computed at several times and at several detector locations. It also required that the shielding calculation be carried out in complex three-dimensional structures. The KAPV program has been selected to perform this function in the Engineering System.

### 2.4.1 Operating Instructions

The INAP version of KAPV is basically as reported in Reference 9 where detailed descriptions of the input variables, output variables and numerical methods may be found. However, the method of reading data into KAPV has been improved to provide the capability to accept alphanumeric, floating, and integer data in any order and intermingled rather than in ordered blocks. As a result of this change the punched output from NAP may be placed behind the data prepared by the user eliminating errors that could arise in inserting cards into and rearranging data decks.

The KAPV program is arranged so that the dose or dose rate is computed at each detector from one source region at a time. As the calculations are repeated, in turn, for each source region the results for each detector are subtotaled. Therefore, there is no limit (other than computer time) to the number of different source region which may be treated. Also this is advantageous for evaluating the importance of each material or activated region to the response at a given detector.

It should also be noted that no capability of the KAPV program has been removed in integrating it into the INAP system. Therefore, neutron problems as well as gamma problems with other than activation sources may be treated if the input routines are modified to read the required input neutron data. KAPV/INAP does not require the following variables which pertain to neutron calculation be input:

NGN	ENN
NRN	XSECN(I,J)
NRSPN	XSNREF
NRSPA	ALFA
INEUT (I)	AWSØUR
KØRD (I)	BKP (I)
IØRD (I)	CØM (I,J,K)
ASØI (20	CØN (I,J,K)
FSI	XLAM
FS (I,J,K)	RSPN (I,J)
NSØUR	RSPA (I,I)
	FSIT (I,J,2)

### 2.4.2 Input Data Instructions

The input data to the INAP Version of KAPV consists of three basic types of input data. These are: alphanumeric data; integer or fixed point data; and real or floating point data as in the original version of KAPV. However, changes were made in the manner and order in which these types of data are specified to provide the flexibility required in the INAP code system. The INAP version of KAPV requires that an alphanumeric identifier precede each block of the basic data types and that alphanumeric identifiers specify the last data for that particular case and the end of the problem. Because the type of data is specified, there is no requirement to order the data. Blocks of data, properly identified, may be interspersed in any order. Also an option exists to specify comment cards for better data description.

In all there are six alphanumeric identifiers, these start in the first column of the card and are: CØMMENT; ALPHANUMERIC; INTEGER; FLØATING; LAST; and END. The CØMMENT identifier is used to identify comment cards and is required on all comment cards. The ALPHANUMERIC, INTEGER and FLOATING identifiers are required on a card preceding the respective data block they identify. The LAST and END identifiers follow the data and indicate, respectively, the end of data for each case and the end of data for that job.

The card format for cards containing data consists of two fields. The first field (card column 1-12) is read in FØRTRAN format (I2,IØ,I9) on all data cards. The first subfield (I2) must contain the number of pieces (i.e., words) of data on the card while the second subfield (I9) must give the address (i.e., storage location) of the first piece of data on the card. The second field (card columns 13-72) may contain either alphanumeric, integer or real data in accordance with the type of data block being read. Since the format of this field varies, the formats are given in the following subsections describing the input data contained in each type of data block. Although this section contains a complete description of the KAPV input data the INAP user should consult Reference 9 for further details

#### 2.4.2.1 Alphanumeric Data

The card format for the alphanumeric or title data is the FORTRAN format, (12, 1X, 19, 15A4). The last 15 data words (card columns 13 - 72) are subdivided into four character alphanumeric data which are input at the discretion of the user.

The relative location or address of the initial four character word in each title section is tabulated and described below and the breakdown of data sections are described. The option to input specific title data was included because of the output flexibility of the program. It must be noted that the user, in specifying a three word title, has the capability of inputting 12 characters of information. In addition, the breakdown of the 180 and 120 character titles into 3 and 2 lines of 15 alphanumeric data words per line (60 characters per line) must be noted by the user to provide clearly titled output results.

<u>ADDRESS</u>	<u>DATA</u>	<u>ARRAY DIMENSION</u>	<u>DESCRIPTION</u>
1	TITLE	(45)	Overall problem title (180 alphanumeric characters) which is output at the beginning of the output printing. (Printed 60 characters to a line.)
46	TITLE	(30)	Title information (120 characters) printed preceding the output of results for each source region and all detection points. (Printed 60 characters to a line.)
76	TITLE	(30)	Title information (120 characters) printed preceding the output of results for the subtotal over a selected set of source regions (i.e., the summation over all reactor subregions). (Printed 60 characters to a line.)
106	TITLE	(30)	Title information (120 characters) printed preceding the output of results for the summation of all source regions, (i.e., summation over subtotals). (Printed 60 characters to a line.)
	TITLE	(3, 10)	Title information (3 words or 12 characters) associated with gamma ray response output data.

<u>ADDRESS</u>	<u>DATA</u>	<u>ARRAY DIMENSION</u>	<u>DESCRIPTION</u>
136	TITLE(1)		Gamma ray response No. 1
139	TITLE(2)		Gamma ray response No. 2
142	TITLE(3)		Gamma ray response No. 3
145	TITLE(4)		Gamma ray response No. 4
148	TITLE(5)		Gamma ray response No. 5
151	TITLE(6)		Gamma ray response No. 6
154	TITLE(7)		Gamma ray response No. 7
157	TITLE(8)		Gamma ray response No. 8
160	TITLE(9)		Gamma ray response No. 9
163	TITLE(10)		Gamma ray response No. 10
166	TITLE	(3, 10)	Title information (3 words or 12 characters) associated with each neutron response output data. Data order identical to gamma ray response data.
196	TITLE	(3, 10)	Title information (3 words or 12 characters) associated with each Albert-Welton response output data. Data order identical to gamma ray response title data.
	TITLE	(3, 25)	Title information (3 words or 12 characters) for each detector point in the problem:
226	TITLE(1)		Detector point 1
229	TITLE(2)		Detector point 2
232	TITLE(3)		Detector point 3
235	TITLE(4)		Detector point 4
.	.		.
.	.		.
291-300	TITLE(25)		Detector point 25
401	TITLE	(30)	Title information (120 characters) printed preceding the output overall source regions for the cumulative time results.

#### 2.4.2.2 Integer or Fixed Point Data

The card format for the integer data is the FORTRAN format (I2, IX, I9, 2013). The last 20 pieces of data (card columns 13-72) are subdivided into three digit fields which are input as "right justified" integer data.

The address of each piece of data, or the address of each data array, is tabulated and described below and those pieces of data which are used as input to NAP or output from NAP in the Engineering INAP system are noted.

<u>ADDRESS</u>	<u>DATA</u>	<u>ARRAY DIMENSION</u>	<u>DESCRIPTION</u>
1'	NGG		Total number of gamma ray groups, $E_g$ . ( $1 \leq NGG \leq 30$ ) (Output by NAP in INAP system)
2	NGN		Total number of neutron groups, $E_n$ . ( $1 \leq NGN \leq 30$ )
3	MAT		Total number of materials or elements (i.e., an element, H, O, or Fe; or a material, $H_2O$ , $UO_2$ ) in the material/composition table. <u>Note:</u> The user may input the data, $\mu_m(E_g)$ for MAT elements, or optionally the program will calculate gamma ray coefficients, $\mu_m(E_g)$ , for MATL elements, but not materials (such as $H_2O$ ). The coefficients, $\mu_m(E_g)$ , calculated by the program are in units of $cm^2/gm$ . The internally generated gamma ray data will appear as the first MATL sets of data in the material/composition table. Therefore, the MAT set of data must correspond up to and including the first MATL set of data. ( $1 \leq MAT \leq 20$ ) and ( $MAT \leq MATL$ )
4	NCØMP		Total number of compositions in the material/composition table. ( $1 \leq NCØMP \leq 50$ )
5	NDET		Total number of detector points to be evaluated for the source region in the problem. The program will accumulate results for multiple source regions for all detector points under the control of the input quantity, ISUM. ( $1 \leq NDET \leq 25$ )

<u>ADDRESS</u>	<u>DATA</u>	<u>ARRAY DIMENSION</u>	<u>DESCRIPTION</u>
6	NBØUND		Total number of boundary surfaces in the problem geometry. (1 ≤ NBØUND ≤ 100)
7	NREG		Total number of geometric regions or zones in the problem geometry. A region is described by 6 or less boundary surfaces which subdivide the overall problem space. (1 ≤ NREG ≤ 100)
8	NRSPG		Total number of sets of response functions to be applied to the calculated gamma ray flux data at each detector point. (1 ≤ NRSPG ≤ 10)
9	NRSPN		Total number of sets of response functions to be applied to the calculated neutron flux data at each detector point. (1 ≤ NRSPN ≤ 10)
10	NRSPA		Total number of response functions to be applied to the Albert-Welton neutron dose function results at each detector point. (1 ≤ NRSPA ≤ 10)
11	MATL		Total number of elements for which gamma ray coefficient sets are to be internally generated by the program. The MATL sets must be the first MAT sets of the material/composition table. (0 ≤ MATL ≤ MAT)
19	IBILD		Control word for buildup factor input data. IBILD=0: input buildup factor polynomial coefficients at location BILD  IBILD>0: The program internally computes the buildup factor coefficients from the library If IBILD=1, H <sub>2</sub> O dose build If IBILD=2, H <sub>2</sub> O energy buildup If IBILD=3, H <sub>2</sub> O energy absorption buildup If IBILD=4, Al dose buildup If IBILD=5, Al energy buildup If IBILD=6, Al energy absorption buildup If IBILD=7, Fe dose buildup If IBILD=8, Fe energy buildup If IBILD=9, Fe energy absorption buildup

<u>ADDRESS</u>	<u>DATA</u>	<u>ARRAY DIMENSION</u>	<u>DESCRIPTION</u>
			If IBILD=10, U dose buildup If IBILD=11, U energy buildup If IBILD=12, U energy absorption buildup If IBILD=13, Pb dose buildup If IBILD=14, Pb energy absorption buildup If IBILD=15, Pb energy absorption buildup If IBILD=17, Sn dose buildup If IBILD=19, Sn energy buildup If IBILD=21, Sn energy absorption buildup If IBILD=23, W dose buildup If IBILD=25, W energy buildup
20	IGAM		Control word for calculation of gamma ray attenuation functions.  IGAM=0: Do not calculate gamma ray attenuation functions.  IGAM=1: Calculate gamma ray attenuation functions. (Output by NAP in INAP system)
	INEUT	(3)	Control words for calculation of neutron attenuation functions.  INEUT (i)=0: Do not calculate neutron attenuation function.  INEUT(i)=1: Calculate neutron attenuation function.
21	INEUT(1)		Control word for Albert-Welton neutron dose calculation.
22	INEUT(2)		Control word for monovariant polynomial, $f(W_R, E_n)$ , neutron spectra calculation.
23	INEUT(3)		Control word for bivariate polynomial, $f(W_R, E_n)$ , neutron spectra calculation.
24	ISCP		Control word for calculation at a detector in the immediate vicinity of source points. (An analytical result is calculated if the path length between a source point and detector point is less than or equal to SMFP mean free paths in the ISCP composition.)

<u>ADDRESS</u>	<u>DATA</u>	<u>ARRAY DIMENSION</u>	<u>DESCRIPTION</u>
24	ISCP		<p>(continued)</p> <p>ISCP=0: Do not calculate analytical result.</p> <p>ISCP&gt;0: Calculate analytic result with the ISCP composition as the source material.</p>
25	IZSØ		<p>The number of the source zone in which all path length calculations are initiated. (Output by NAP in INAP system)</p> <p>IZSØ=Source zone number.</p>
26	ISØRC		<p>Control word for calculation of all source distribution functions. (Output by NAP in INAP system)</p> <p>ISØRC=0: Do not calculate source distribution data but use previous problem data.</p> <p>ISØRC=1: Calculate new source distribution data from RS, ZS, PHI, and FSI input data.</p>
27	ISRC		<p>Control word for the calculation of radial source distribution data. (Output by NAP in INAP system)</p> <p>ISRC=0: Do not calculate and renormalize input data, but use RS, ZS, PHI, and FSI as point source data. (This option allows the description of one or more discrete point sources.)</p> <p><u>NOTE:</u> The following radial source distribution options are applicable to a cylindrical source geometry.</p> <p>ISRC=1: Uniform or flat source distribution (Does not require FSI input).</p> <p>ISRC=2: Cosine source distribution based on input data, XI's. (Does not require FSI input).</p> <p>ISRC=3: Source distribution based on a linear variation of input data, FSI, between mesh points, RS.</p> <p>ISRC=4: Source distribution based on input exponential distribution data XI's. (Does not require FSI input).</p> <p>ISRC=5: Source distribution based on exponential variation of input data, FSI, between mesh points, RS.</p>

<u>ADDRESS</u>	<u>DATA</u>	<u>ARRAY DIMENSION</u>	<u>DESCRIPTION</u>
27	ISRC		<p>(continued)</p> <p><u>NOTE:</u> The following radial source distribution options are applicable to a spherical source geometry.</p> <p>ISRC=6: Uniform or flat source distribution. (Does not require FSI input data).</p> <p>ISRC=7: Source distribution based on a linear variation of input data, FSI, between mesh points, RS.</p>
28	ISZC		<p>Control word for axial or polar source distribution calculations. (Output by NAP in INAP system)</p> <p><u>NOTE:</u> The following source distribution options are applicable to cylindrical source geometry.</p> <p>ISZC=1: Uniform or flat source distribution (Does not require FSI input).</p> <p>ISZC=2: Cosine source distribution based on the input data, ETA. (Does not require FSI input data).</p> <p>ISZC=3: Source distribution based on the linear variation of input data, FSI, between the mesh points, ZS.</p> <p>ISZC=4: Source distribution based on an exponential variation of the source between mesh points, ZS, and the input data, ETA. (Does not require FSI input data).</p> <p>ISZC=5: Source distribution based on the exponential variation of the source between mesh points, ZS. (Requires FSI input data).</p> <p><u>NOTE:</u> The following source distribution option is applicable to a spherical source geometry.</p> <p>ISZC=6: Uniform or flat polar variation. (Does not require FSI input data).</p>
29	ISTC		<p>Control word for azimuthal source description. (Input to NAP and output by NAP in INAP system).</p> <p><u>NOTE:</u> All azimuthal source distributions are assumed to be uniform. The user must use the ISRC=0 option with all input data calculated externally to the program to do otherwise.</p> <p>ISTC=1: Aximuthal source point spacing from the input data, PHI, with <math>NS\phi(1)</math> intervals in each radial interval.</p>

<u>ADDRESS</u>	<u>DATA</u>	<u>ARRAY DIMENSION</u>	<u>DESCRIPTION</u>
29	ISTC		<p>(continued)</p> <p>ISTC=2: Azimuthal source point spacing from the input data, PHI, with the number of azimuthal intervals for each radial interval set by the input data, NSØ.</p> <p>ISTC=3: Azimuthal source point spacing based on equal azimuthal intervals; the number of intervals is set by the input data, NSØ.</p>
30	ISIT		<p>Control word for source distribution interpolation calculation.</p> <p>ISIT=0: Do not interpolate RSIT, ZSIT, FSIT input data to obtain FSI at RS and ZS.</p> <p>ISIT=1: Interpolate RSIT, ZSIT, FSIT input data to obtain FSI at RS and ZS.</p>
31	ISUM		<p>Control word for summation of the contribution of individual source regions to the detector response at each detector point. (Input to NAP and output by NAP in INAP system).</p> <p>ISUM=0: Do not include this region in the summation of individual source region results.</p> <p>ISUM=1: Start summing individual source region results beginning with this region.</p> <p>When ISUM=-1: The storage allocated for the grand total and subtotal is set to zero. The results for the region are added to the grand total and subtotal. Then ISUM is set equal to +1.</p> <p>ISUM=+1: Add individual source region results to the grand total and the subtotal.</p> <p>ISUM=2: Add the contribution of the source region to the subtotal and grand total, print the subtotal, then set the subtotal to zero.</p> <p>ISUM=3: Add the contribution of the source region to the subtotal and the grand total, print the subtotal and the grand total, set the grand total and subtotal to zero.</p>
32	IØUT(1)		<p>Control word for printing <u>input</u> data.</p> <p>IØUT(1)=0: Do not print input data.</p> <p>IØUT(1)=1: Print card images of input data.</p> <p>IØUT(1)=2: Print card images and organized input data.</p>

<u>ADDRESS</u>	<u>DATA</u>	<u>ARRAY DIMENSION</u>	<u>DESCRIPTION</u>
32	IØUT(1)		(continued) <u>NOTE:</u> Normalized source distribution data are printed only when IØUT(1)=2.
33	IØUT(2)		Control word for printing of <u>output data</u> . IØUT(2)=1: Do not print individual source region results. IØUT(2)=0: Print all output data for each individual source region.
	KØRD	(3)	Degree or order for each set of the neutron moments method bivariate polynomial data in the independent variable, energy ( $E_n$ ).
35	KØRD(1)		Degree or order of the first set of coefficients for the energy range, BKP(1) to BKP(2).
36	KØRD(2)		Degree or order of the second set of coefficients for the energy range, BKP(2) to BKP(3).
37	KØRD(3)		Degree or order of the third set of coefficients for the energy range, BKP(3) to BKP(4).
	IØRD	(3)	Degree or order for each set of the neutron moments method bivariate polynomial data in the independent variable, depth penetration ( $W_R$ ).
40	IØRD(1)		Degree or order of the first set of coefficients for the energy range, BKP(1) to BKP(2).
41	IØRD(2)		Degree or order of the second set of coefficients for the energy range, BKP(2) to BKP(3).
42	IØRD(3)		Degree or order of the third set of coefficients for the energy range, BKP(3) to BKP(4).
50	LSØ		Total number of radial mesh intervals in the source region description. ( $1 \leq LSØ \leq 20$ ) (Input to NAP and output by NAP in INAP system).

<u>ADDRESS</u>	<u>DATA</u>	<u>ARRAY DIMENSION</u>	<u>DESCRIPTION</u>
51	MSØ		Total number of axial or polar mesh intervals in the source region description. ( $1 \leq MSØ \leq 20$ ) (Input to NAP and output by NAP in INAP system).
	NSØ	(20)	Total number of azimuthal mesh intervals for each radial interval in the source region description. ( $1 \leq NSØ(1) \leq 20$ ) (Input to NAP and output by NAP in INAP system).
52	NSØ(1)		Total number of azimuthal mesh intervals in radial interval number 1 or if, $ISTC=1$ , the total number of intervals in each radial interval.
53	NSØ(2)		Total number of azimuthal mesh intervals in radial interval 2.
.	.		.
.	.		.
.	.		.
71	NSØ(20)		Total number of azimuthal mesh intervals in radial interval 20.
75	LSIT		Total number of radial source distribution input data values, RSIT and FSIT, to be used in interpolation of source distribution data, FSI, at the mesh points RS. ( $1 \leq LSIT \leq 21$ )
76	MSIT		Total number of axial source distribution input data values, ZSIT and FSIT, to be used in interpolation of source distribution data, FSI, at the mesh points, ZS. ( $1 \leq MSIT \leq 21$ )
	NEQBD(i)	(100)	Surface equation type number for each surface or boundary, i, in the problem. (The surface equations and their respective type number are presented preceding the surface equation coefficient input description). ( $1 \leq NEQBD(i) \leq 6$ )
100	NEQBD(1)		Type number for surface No. 1.
101	NEQBD(2)		Type number for surface No. 2.
.	.		.
.	.		.
.	.		.

<u>ADDRESS</u>	<u>DATA</u>	<u>ARRAY DIMENSION</u>	<u>DESCRIPTION</u>
199	NEQBD(100)		Type number for surface No. 100.
	NBNDZN(i)	(100)	The total number of boundaries or surfaces defining each zone, i, in the problem. Each zone must have at least one boundary and no more than six boundaries. ( $1 \leq \text{NBNDZN}(i) \leq 6$ ). <u>NOTE:</u> The sign (+) of NBNDZN(i) denotes whether the zone is an outside or last zone and the user must specify this sign. If NBNDZN is negative, the zone is an outside or last zone.
200	NBNDZN(1)		Total number of boundary surfaces for zone No. 1.
201	NBNDZN(2)		Total number of boundary surfaces for zone No. 2.
.	.		.
.	.		.
.	.		.
299	NBNDZN(100)		Total number of boundary surfaces for zone No. 100.
	NCMPZN(1)	(100)	The composition number of the mixture of materials in zone, i, for each zone in the problem.
300	NCMPZN(1)		Composition number in zone 1.
301	NCMPZN(2)		Composition number in zone 2.
.	.		.
.	.		.
.	.		.
399	NCMPZN(100)		Composition number in zone 100.
	LBD(j,i)	(6,100)	The boundary surface numbers, j, for each zone, i. The user must specify NBNDZN(i) surface numbers for each zone, i, and the surfaces must totally enclose the zone or region in the problem. Outside zones can be described as single boundary zones. <u>NOTE:</u> The KAPV program will automatically assign all ambiguity indices (+ or -) of each surface, j, in relation to each zone, i.
500	LBD(j,1)		Surface numbers, j=1, NBNDZN(1), for zone 1.
506	LBD(j,2)		Surface numbers, j=1, NBNDZN(1), for zone 2.

<u>ADDRESS</u>	<u>DATA</u>	<u>ARRAY DIMENSION</u>	<u>DESCRIPTION</u>
506	LBD(j,1)		(continued)
.	.		.
.	.		.
.	.		.
1094	LBD(j,100)		Surface numbers, j=1, NBNDZN(1), for zone 100.
	NTRYZN(j,i)	(6,100)	The zone identification number for each boundary, j, of each zone, i, which defines the zone encountered upon crossing each boundary of the zone, i. There is a one to one correspondence between LBD and NTRYZN.  <u>Note:</u> If more than one zone can be entered upon crossing boundary, j, the user can minimize problem running times by specifying the zone entered the most times, or if this cannot be determined, the zone with the lower identification number.
1100	NTRYZN(j,i)		Zone number, j=1, NBNDZN(1), for zone 1.
1106	NTRYZN(j,2)		Zone number, j=1, NBNDZN(1), for zone 2.
.	.		.
.	.		.
.	.		.
1694	NTRYZN(j,100)		Zone number, j=1, NBNDZN(1), for zone 100.

#### 2.4.2.3 Real or Floating Point Data

The card format for the real data is the FØRTRAN format (I2, 1X, I9, 5E12.5). The last 5 pieces of data (card columns 13-72) are subdivided into twelve digit fields which are input as real or floating point data.

The relative location or address of each piece of data, or the initial address of each data array, is tabulated and described below and those pieces of data which are input to NAP or output from NAP in the Engineering INAP system are noted. The addressing of data internal to a data array is also tabulated and described.

<u>ADDRESS</u>	<u>DATA</u>	<u>ARRAY DIMENSION</u>	<u>DESCRIPTION</u>
	ASØ1	(2)	Gamma ray and neutron source normalization constants. The input constants, ASØ1, must be dimensionally consistent with GSØUR, NSØUR, and AWSØUR to provide particles/cm <sup>3</sup> -sec.
1	ASØ1(1)		Gamma ray source normalization constant. (Output by NAP in INAP system)
2	ASØ1(2)		Neutron source normalization constant.
			<u>NOTE:</u> If ASØ1(2) is input as 0.0, the program assumes ASØ1(2)=ASØ1(1) and all gamma ray source distribution data, FSI, are also used for neutron source calculations.
	XI	(2)	Radial source distribution constants used in the truncated cosine or exponential source distribution function.
			<u>For truncated cosine,</u>
3	XI(1)		= $\pi/R^*$ , where $R^*$ is the extrapolated region radius.
4	XI(2)		= 0.0
			<u>For exponential</u>
3	XI(1)		= $f(R_0)$ , the source value at the left boundary radius, $R_0$ .
4	XI(2)		= $\sigma$ , the slope of the source distribution in the region.
	ETA	(2)	Axial source distribution constants used in the truncated cosine or exponential source distribution function.
			<u>For truncated cosine</u>
5	ETA(1)		= $\frac{\pi}{H^*}$ , where $H^*$ is the extrapolated height.
6	ETA(2)		= $\frac{H^*}{2}$
			<u>For exponential</u>
5	ETA(1)		= $f(Z_0)$ , the source value at the left axial boundary, $Z_0$ .
6	ETA(2)		= $\sigma$ , the slope of the source distribution in the region.
7	RS(i)	(21)	Radial dimensions of the source region mesh intervals. (LSØ + 1 values) (Output by NAP in INAP system).

<u>ADDRESS</u>	<u>DATA</u>	<u>ARRAY DIMENSION</u>	<u>DESCRIPTION</u>
28	ZS(m)	(21)	Axial or polar dimensions of source region mesh intervals. (MSØ + 1 values) (Output by NAP in INAP system).
	PHI(n,i)	(21,20)	Azimuthal dimensions of source region mesh intervals for each radial interval, i. (Input to NAP and output by NAP in INAP system).
49	PHI(n,1)		Dimensions of radial Interval No. 1, (NSØ(1) + 1 values)
.	.		.
.	.		.
.	.		.
448	PHI(n,20)		Dimensions of radial interval No. 20, (NSØ(20)+ 1 values)
	FSI	(21,22,2)	NOTE: PHI(n,i) for K greater than 1 are required only when for ISTC>2 Source distribution data for radial, axial, or polar, and azimuthal distribution for both gamma ray, K=1, and neutron, K=2, source data.
470	FSI(1,1,1)		Gamma ray radial source data, (LSØ + 1 values)
491	FSI(m,2,1)		Gamma ray axial or polar source data, (MSØ + 1 values)
512	FSI(n,3,1)		Gamma ray azimuthal data for each radial interval, (NSØ(1) + 1 values) NOTE: FSI(n,3,1) is required input only for the case when the user specifies all source data FSI as input (i.e., a unit point source is input by specifying ISØRC=1, ISRC=0, FSI(470)=1.0, FSI(491)=1.0, FSI(512)=1.0)
512	FSI(1,3,1)		Gamma ray azimuthal data for radial interval No. 1.
533	FSI(2,3,1)		Gamma ray azimuthal data for radial interval No. 2
.	.		.
.	.		.
.	.		.
931	FSI(20,3,1)		Gamma ray azimuthal data for radial interval No. 20.

<u>ADDRESS</u>	<u>DATA</u>	<u>ARRAY DIMENSION</u>	<u>DESCRIPTION</u>
932	FSI(1,1,2)		Neutron source distribution data input which is identical in order with the gamma ray data, but with all addresses increased by 462.  <u>NOTE:</u> If ASØI(2) is input as 0.0, then FSI(1,1,2)= FSI(1,1,1).
1400	GSØUR	(30)	Gamma ray source by energy group, ENG.  <u>NOTE:</u> GSØUR must be dimensionally consistent with ASØI(1), so that GSØUR(k)*ASØI(1) will provide the units of particles or Mev/cm <sup>3</sup> -sec. (Output by NAP in INAP System)
1430	NSØUR	(30)	Neutron source by energy group, ENN.  <u>NOTE:</u> NSØUR must be dimensionally consistent with ASØI(2). These quantities provide the user with the capability to input group dependent integration factors (energy band widths) and <u>must not be</u> construed as neutron source spectra.

The following input data (ABD, BBD, CBD, XOBD, YOBD, ZOBD, DBD) are the surface equation coefficients and constants for each boundary (1-100). This input depends on the boundary or surface equation type. The surface equation types which are in the program are the general quadratic equation types which are in the program are the general quadratic equation, and five of the common degenerate forms, as shown below:

<u>SURFACE EQUATION TYPE</u>	<u>EQUATION</u>
1	$AX^2 + XX_0 + BY^2 + YY_0 + CZ^2 + ZZ_0 = D$
2	$A(X - X_0)^2 + B(Y - Y_0)^2 + C(Z - Z_0)^2 = D$
3	$(X - X_0)^2 + (Y - Y_0)^2 = D$
4	$X = D$
5	$Y = D$
6	$Z = D$

<u>ADDRESS</u>	<u>DATA</u>	<u>ARRAY DIMENSION</u>	<u>DESCRIPTION</u>
1460	ABD	(100)	Surface equation coefficient constant, A, for surfaces 1-100.
1560	BBD	(100)	Surface equation coefficient, B, for surfaces 1-100.
1660	CBD	(100)	Surface equation coefficient, C, for surfaces 1-100.
1760	XOBD	(100)	Surface equation constant, $X_0$ , for surfaces 1-100.
1860	YOBD	(100)	Surface equation constant, $Y_0$ , for surfaces 1-100.
1960	ZOBD	(100)	Surface equation constant, $Z_0$ , for surfaces 1-100.
<p><u>NOTE:</u> To eliminate errors in path length calculations, the program automatically squares the input quantity, D, for surface equation types 2 and 3 to provide absolute matching of surface intersections. Therefore, input the quantity, D, as the radius of interest.</p>			
	XYZ(j,i)	(3,100)	Cartesian coordinates of the point internal to each zone, i, described by the input data, LBD. There are 3 x NREG required input values. These data are used in computing the ambiguity indices (+ or -) of each surface in relation to the zone and extreme caution must be used in determining input values.
2160	XYZ(j,1)		$(X_p, Y_p, Z_p)$ for zone 1.
2163	XYZ(j,2)		$(X_p, Y_p, Z_p)$ for zone 2.
.	.		.
.	.		.
.	.		.
2397	XYZ(j,100)		$(X_p, Y_p, Z_p)$ for zone 100.
	CØMP(m,n)	(20,50)	Composition matrix (densities or volume fractions) according to the materials or elements, m, in the problem.

<u>ADDRESS</u>	<u>DATA</u>	<u>ARRAY DIMENSION</u>	<u>DESCRIPTION</u>
2460	CØMP(m,1)		CØMP(m,1): data for all materials, m, in composition 1.
2480	CØMP(m,2)		CØMP(m,2): data for all materials, m, in composition 2.
.	.		.
.	.		.
.	.		.
3440	CØMP(m,50)		CØMP(m,50): data for all materials, m, in composition 50.
3460	ENN	(30)	Representative energy of each neutron group.
	XSECN(m,i)	(20,3)	Data for the Albert-Welton and neutron spectra functions.
3490	XSECN(m,1)		Neutron removal cross sections for each material for use with the Albert-Welton function.
3510	XSECN(m,2)		Constants ( $\mu$ 's) for each material for use with the Albert-Welton function.
3530	XSECN(m,3)		Neutron removal cross sections for each material for use with the neutron spectra function.
3550	XSNREF		Neutron removal cross section for the material for which the neutron moments data is input (reference material removal cross section).
3551	ALFA	(7)	Constants ( $\alpha$ 's) for the Albert-Welton function.
3558	AWSØUR		Source strength to be applied to the Albert-Welton kernel. <u>NOTE:</u> AWSØUR must be dimensionally consistent with ASØI(2).
3560	ENG	(30)	Representative energy of each gamma ray source group. (Output by NAP in INAP system)
	XSECG(k,m)	(30,20)	Gamma ray absorption coefficients for each group, k, and each material, m, in the problem. The program will generate these data from tables and/or polynomial evaluation if requested.
3590	XSECG(k,1)		Coefficients for each group k, material 1.

<u>ADDRESS</u>	<u>DATA</u>	<u>ARRAY DIMENSION</u>	<u>DESCRIPTION</u>
3620	XSECG(k,2)		Coefficients for each group k, material 2.
.	.		.
.	.		.
.	.		.
4161	XSECG(k,30)		Coefficients for each group k, material 30.
	BILD(1,k)	(4,30)	Gamma ray cubic polynomial build up coefficients for each gamma ray group, k.
			NOTE: The program will internally compute these data if so requested.
4190	BILD(1,1)		$\beta_0, \beta_1, \beta_2, \beta_3$ for group 1.
4194	BILD(1,2)		$\beta_0, \beta_1, \beta_2, \beta_3$ for group 2.
.	.		.
.	.		.
.	.		.
4306	BILD(1,30)		$\beta_0, \beta_1, \beta_2, \beta_3$ for group 30.
4310	SMFP		Total mean free path of source material (source composition ISCP) used in determining the exclusion sphere volume for source points adjacent to detector points. This quantity is used in the empirical solution of the gamma ray flux for detector points internal to source regions.
4311	TMFP		The limit or maximum range of mean free paths of gamma ray depth penetration for cubic polynomial buildup data. The program calculates buildup only on TMFP (or less) mean free paths. If the mean free path exceeds TMFP, the program sets the mean free path equal to TMFP. The program assumes TMFP = 20, if TMFP is not input.
4312	EPSLN		Surface equation-path length calculation error limit used in determining if a surface is crossed. If the test fails, an error statement is given.
			NOTE: EPSLN is internally set as $1.0 \times 10^{-6}$ and is not required as input if the user accepts this value.

<u>ADDRESS</u>	<u>DATA</u>	<u>ARRAY DIMENSION</u>	<u>DESCRIPTION</u>
4313	FUDGE		<p>Surface equation-path length calculation step quantity used in providing a means for the calculation to cross a boundary. If two steps are unsuccessful, an error statement is given.</p> <p>NOTE: FUDGE is internally set as <math>1.0 \times 10^{-3}</math> and is not required as input if the user accepts this value.</p>
4314	BKP(i)	(4)	<p><u>For Monovariant Neutron Spectra Data:</u></p> <p>The neutron depth penetration, <math>\text{gm/cm}^2</math>, which is the breakpoint between the two sets of monovariant moments method data. Only BKP(1) is required.</p> <p><u>For Bivariant Neutron Spectra Data:</u></p> <p>The neutron energy breakpoints for the applicability of the bivariant polynomial data. BKP(1-4) must be in order of decreasing energy and the last values 2, 3 or 4 must not be zero (e.g., for only one set of polynomial data, BKP(1) = E(higher) and BKP(2,3, and 4) = E(lower).</p>
	CØM	(5,30,2)	<p>Neutron spectra monovariant polynomial coefficients for NGN groups. This data, which is evaluated as a function of depth penetration (<math>W</math>, <math>\text{gm/cm}^2</math> of equivalent neutron attenuation), is assumed to be applicable in the range of <math>0.0 &gt; W &gt; 120.0 \text{ gm/cm}^2</math>. The two sets of input data divide this range into, <math>0.0 &gt; W &gt; \text{BKP}(1)</math> and <math>\text{BKP}(1) &gt; W &gt; 120.0</math>. For any depth penetration in excess of <math>120.0 \text{ gm/cm}^2</math>, the group dependent <math>\lambda</math>'s (input quantities, XLAM) are used as simple exponential attenuation as, <math>\exp[-\lambda(W-120.0)]</math>.</p>
4320	CØM(i,1,1)		<p>CØM(1-5): <math>C_5, C_4, C_3, C_2, C_1</math> for group 1, and <math>W &lt; \text{BKP}(1)</math>.</p>
4325	CØM(i,2,1)		<p>CØM(1-5): <math>C_5, C_4, C_3, C_2, C_1</math> for group 2, and <math>W &lt; \text{BKP}(1)</math>.</p>
.	.		.
.	.		.
.	.		.
4460	CØM(i,30,1)		<p>CØM(1-5): <math>C_5, C_4, C_3, C_2, C_1</math> for group 30, and <math>W &lt; \text{BKP}(1)</math>.</p>

<u>ADDRESS</u>	<u>DATA</u>	<u>ARRAY DIMENSION</u>	<u>DESCRIPTION</u>
4470	CØM(i,1,2)		CØM(1-5): $C_5, C_4, C_3, C_2, C_1$ for group 1, and $W \geq BKP(1)$ .
4475	CØM(i,2,2)		CØM(1-5): $C_5, C_4, C_3, C_2, C_1$ for group 2, and $W \geq BKP(1)$ .
.	.		.
.	.		.
.	.		.
4615	CØM(i,30,2)		CØM(1-5): $C_5, C_4, C_3, C_2, C_1$ for group 30, and $W \geq BKP(1)$ .
	CØN	(5,5,4)	Neutron spectra bivariate polynomial coefficients. These data, which are evaluated as a function of depth penetration, $W$ , and neutron energy, $E_n$ , is assumed applicable over the entire range of $W \geq 120.0$ gm/cm <sup>2</sup> . The four sets of data divide the energy range into four intervals as determined by BKP(1-4). Calculations for $W$ in excess of 120.0 gm/cm <sup>2</sup> are discussed above in the monovariant polynomial description.
4620	CØN(5,5,1)		CØN(1-25): $C_1, C_2, C_3, C_4, C_5, \dots, C_{25}$ for $BKP1 \geq E \geq BKP2$ .
4645	CØN(5,5,2)		CØN(1-25): $C_1, C_2, C_3, \dots, C_{25}$ for $BKP2 \geq E \geq BKP3$ .
4670	CØN(5,5,3)		CØN(1-25): $C_1, C_2, C_3, \dots, C_{25}$ for $BKP3 \geq E \geq BKP4$ .
.	.		.
.	.		.
.	.		.
4695	CØN(5,5,4)		CØN(1-25): $C_1, C_2, C_3, \dots, C_{25}$ for $E \geq BKP4$ .
4720	XLAM	(30)	Values of $\lambda(E_n)$ for each neutron energy group for use in extrapolating either the monovariant or bivariate neutron spectra data for values of $W \geq 120.0$ gm/cm <sup>2</sup> .
	RSPG	(30,10)	Group-dependent gamma ray response functions. The user must input at least one set of data. If collided and uncollided energy flux is desired as output data, one set of RSPG values must be input as 1.0. The program will provide NRSPG sets of data, and the sum or total over NGG groups for each response function.

<u>ADDRESS</u>	<u>DATA</u>	<u>ARRAY DIMENSION</u>	<u>DESCRIPTION</u>
4750	RSPG(k,1)		Response function No. 1, for each energy group, k.
4780	RSPG(k,2)		Response function No. 2, for each energy group, k.
.	.		.
.	.		.
.	.		.
5020	RSPG(k,10)		Response function No. 10, for each energy group, k.
	RSPN	(30,10)	Group dependent response functions for the neutron spectra data. The user must input at least one set of data. If the total (sum over groups) response is desired, (i.e., total neutrons/cm <sup>2</sup> -sec) the energy width for each group must appear in RSPN or in the neutron group source, NSØUR.
5050	RSPN(i,1)		RSPN is input in the same order as RSPG starting with address, 5050.
5350	RSPA	(1,10)	Response functions for the Albert-Welton function. The user must input at least one value of RSPA (i.e., RSPA (1) = 1.0). The program will provide NRSPA values of output.
	RCØRD	(3,25)	Detector point coordinates ( $R_D$ , $Z_D$ , $\theta_D$ ) for NDET detector points. <u>The detector points must not lie on a boundary of a zone.</u> A maximum of 25 detector points per problem are permitted.
5360	RCØRD(i,1)		( $R_D$ , $Z_D$ , $\theta_D$ ), for detector No. 1.
5363	RCØRD(i,2)		( $R_D$ , $Z_D$ , $\theta_D$ ), for detector No. 2.
5369	RCØRD(i,3)		( $R_D$ , $Z_D$ , $\theta_D$ ), for detector No. 3.
.	.		.
.	.		.
.	.		.
5435	RCØRD(i,25)		( $R_D$ , $Z_D$ , $\theta_D$ ), for detector No. 25.

<u>ADDRESS</u>	<u>DATA</u>	<u>ARRAY DIMENSION</u>	<u>DESCRIPTION</u>
5510	SSOT	(3)	Source region translation coordinates ( $X_T$ , $Y_T$ , $Z_T$ ). The values of SSOT may be used to translate the source region in the problem geometry so that the input source data can be relative to (0,0,0).

THE FOLLOWING INPUT DATA ARE REQUIRED ONLY IF MATL IS GREATER THAN ZERO

5513	ZAT	(20)	Atomic number (electrons per atom) of each element for which gamma ray absorption coefficients, are to be calculated by the program. The calculated values, in units of $\text{cm}^2/\text{gm}$ , will appear as the first MATL sets of gamma ray absorption coefficients. If coefficients are input in conjunction with calculated values, then the input values must be the MATL+1 to MAT sets of values.
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THE FOLLOWING INPUT DATA ARE REQUIRED ONLY IF LIST IS GREATER THAN 0

5533	RSIT	(21)	Radial coordinates of source distribution data to be used in the source interpolation routine. There are LSIT values required. The range of RSIT should be greater than or equal to the range of the radial values, RS, so that only interpolation of data is used.
5554	ZSIT	(21)	Axial coordinates of the source distribution data to be used in the source interpolation routine. There are MSIT values required. The range of ZSIT should be greater than or equal to the range of the axial values, ZS, so that only interpolation is used.
	FSIT(i,k)	(21,2,2)	Source distribution data to be used in the source interpolation routine. There are LSIT and MSIT values required. Source interpolation is calculated for both gamma ray and neutron source distributions.
5575	FSIT(i,1,1)		Radial gamma ray source data.
5596	FSIT(i,2,1)		Axial gamma ray source data.
5617	FSIT(i,1,2)		Radial neutron source data.
5638	FSIT(i,2,2)		Axial neutron source data

<u>ADDRESS</u>	<u>DATA</u>	<u>ARRAY DIMENSION</u>	<u>DESCRIPTION</u>
5661	TIME1		Initial time of time interval for dose calculations or time at which dose rate calculation is being made. (Output by NAP in INAP system)
5662	TIME2		End time of time interval for dose calculation. (Output by NAP in INAP system)

### 2.4.3 Output Description

The KAP-V output data is dependent upon the input control words IØUT (1) and IØUT (2) entered at address 32 and 33, respectively. The control word IØUT (1) controls the printout of the input data. The control word IØUT (2) controls the printout of the output data.

#### 2.4.3.1 Input Data Printout

The printout of the input data will be described first. If IØUT (1) is set at zero, no input data will be printed except the program title. This is followed by the output data described in Section 2.4.3.2.

If IØUT (1) is set equal to one, the image of each input data card as used by the computer is printed. Therefore, only columns 1 to 72 are printed.

If IØUT (1) is set equal to two, the input data is printed out as described for IØUT (1) equal to one plus a set of labeled input data. This labeled printout is self explanatory. Included in the labeled printout are the normalized source distribution data. The labeled printout of the input is followed by the output described in the next section.

#### 2.4.3.2 Output Data Printout

The output printout is obviously dependent upon the types of material attenuation functions that are requested in a particular problem. The output is also dependent upon the ISUM Control (address 31), and the IØUT (2) Control (address 33).

If IØUT (2) is set equal to zero, output is printed for each individual source region in the problem. If IØUT (2) is equal to one, the output for each source region is not printed out. (A NOTE OF CAUTION: If the problem contains only one source region, IØUT (2) must be set equal to zero in order to obtain any answers).

The control word (ISUM) controls the subtotal output over various source regions, and the grand total output over all source regions, as described in the input data instructions.

If a gamma ray calculation is performed, the collided fluxes multiplied by each set of response functions is printed for the first detector point, for each gamma ray group, as well as the total. This is followed by the uncollided gamma ray data.

If an Albert-Welton calculation is performed, the output multiplied by the response functions follows the gamma ray output data.

If neutron spectra are calculated, the neutron spectra data multiplied by the response functions are then printed.

At the end of the output data for each detector point, a comment is printed which tells the program user how many times the value of 20.0 mean free paths, for gamma rays, or  $120.0 \text{ gm/cm}^2$ , for neutrons, was exceeded for a source region.

If a dose calculation is performed, the cumulative time results for all source regions are printed.

## 2.5 System Operation

The programs of the INAP Engineering System are executed in succession with input data as shown in Figure 2.5-1. The data transferred from any one program module to the following (also shown in Figure 2.5-1) are all contained on punched cards which are placed with the input data prepared by the user. The input routines of the programs have been changed so that the user is never required to insert cards or collate input decks. In the following paragraphs the operation of the Engineering System is described.

The neutron transport module, DØT, is executed first to determine the space dependent neutron flux in the region that is being activated. This region will become the source region for the gamma ray shielding module. Therefore, the boundaries and volumes of the zones over which the neutron flux is averaged and assumed flat are punched along with the average flux for input into NAP. All the data punched by DØT is for input into NAP.

The finite cylindrical (r,z) coordinate option of the DØT program is recommended for use in the INAP System since it is most capable of approximating real, finite configurations. With this option the source geometry is passed through NAP to KAPV with very little interaction required of the user. However, the infinite rectangular cylindrical geometry (x,y) option may also be used but the user must prepare the source geometry input for KAPV himself. Since judgment is required to determine the manner in which each two-dimensional geometry should be truncated and altered for input into the three-dimensional KAPV program, this capability could not be implemented in the Code System. The user may also employ DØT (rather inefficiently) to perform one-dimensional slab calculations using the (X,y) option with the periodic boundary condition to extend an additional direction to infinity.

NAP input routines have been modified to accept those variables which complete the description of the gamma source. These variables, listed in Figure 2.5-1 and described in Section 2.4.2, are output by NAP with the gamma source for input to KAPV. NAP will prepare the data for the appropriate number of KAPV cases. In effect, each activated source zone for each time or time range is treated as a separate case, however,

the dose information is summed for each detector and a grand total is printed after all source regions have been treated. The user need prepare only one set of input data regardless of the number of source regions or time ranges considered.

Since DØT and NAP serve to prepare the gamma ray source input for KAPV, the gamma ray shielding module; the user may investigate the effect of alternative shield designs without repeating the DØT and NAP calculations. Also, if it is desired to investigate the effect of activating isotopes which do not significantly effect the neutron self shielding the user need not repeat the DØT calculation but will have to repeat the NAP and KAPV calculations.

To exercise the Engineering System, the user must prepare all the input for the DØT neutron calculation. The punched cards prepared by DØT are then placed before the input data deck prepared by the user for input into NAP for the activation gamma source strength calculation. The first card punched by DØT is a header card which may be replaced by the user if a more descriptive heading for the NAP output is desired. NAP will prepare a deck of punched cards which is then placed behind the KAPV input data deck prepared by the user for the gamma ray shielding calculation.



## 2.6 Engineering System Sample Problem

This section briefly describes a sample problem for the INAP Engineering System and gives card images of the input required by each component program. To conserve space only the output relevant to the INAP System which is sufficient to verify the system operation is shown. Card input prepared by a component code and not the user are enclosed in boxes for identification.

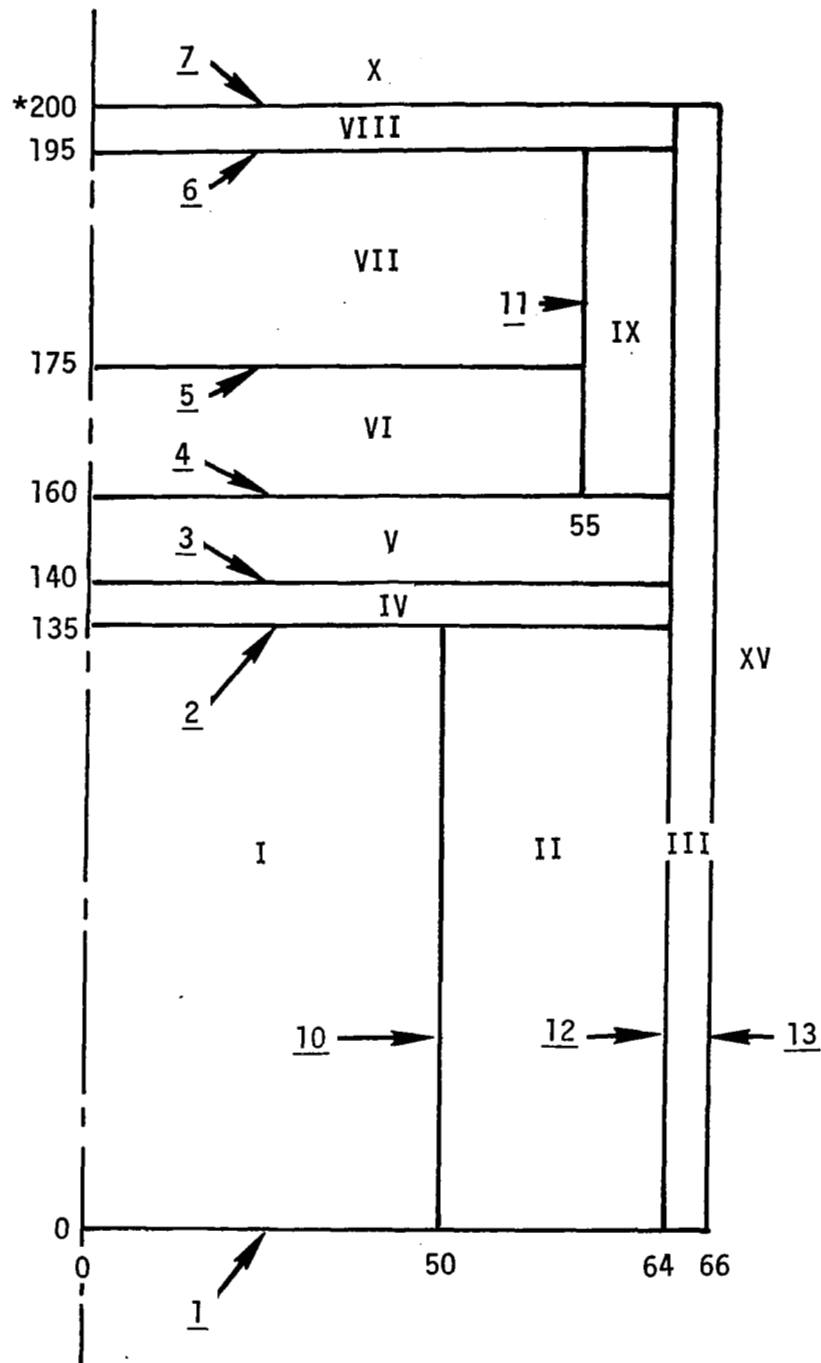
The sample problem for the Engineering System consists of a simplified reactor section and a section of a fuel storage tank. (Figures 2.6-1 and 2.6-2). The DØT calculation is an r-z, 3 group (Table 2.6-1) distributed neutron source calculation using an  $S_6$  quadrature. There are 220 intervals (20 z's and 11 r's), 9 zones, and 5 materials. The zone locations are shown in Figure 2.6-1 and their compositions are given in Table 2.6-2. All input to the DØT calculation is prepared by the user. The first three pages of card images contain the DØT input for the sample problem. The punched card output to be used by NAP is on page 107. An additional card is generated by DØT. This is a header card which may be replaced or used as the header card for the NAP input. In the sample problem this card has been replaced by a more descriptive header card.

The NAP calculation considers only regions I, III, V, VI, and VIII and materials, Fe,  $U^{235}$ ,  $U^{238}$ , and Al which can result in significant production of activation gamma rays. The source is a constant power pulse of one hour duration and the decay chain calculations are carried out to 1000 hours. Two times were chosen for dose calculations by KAPV. These are 7.5 hours and 650.0 hours. The gamma group structure used by NAP and KAPV is given in Table 2.6-1. NAP input is shown on pages 107 through 108. The punched output passed on to the KAPV part of the system is shown on pages 111 to 115.

The KAPV calculation consists of 18 zones (see Figures 2.6-1 and 2.6-2), 5 gamma groups, and 3 detector locations (see Figure 2.6-2). The compositions of the zones are given in Tables 2.6-2 and 2.6-3 and the location and types of boundary surfaces are given in Table 2.6-4. The KAPV/INAP print out is given on page 116 for detector 2 at time 650 hours.

Listing the entire output of each code in the System is extensive, therefore, only the most relevant output information is provided in this report. All program listings as well as sample problem input and output have been placed on magnetic tapes.

\*DIMENSIONS IN CENTIMETERS



NOTES:

- 1) Zones are identified by Roman numerals and surfaces by Arabic numbers underlined.
- 2) Zones I through IX are modeled in the DØT Program.

FIGURE 2.6-1 GEOMETRY OF CORE REGION FOR SAMPLE PROBLEM

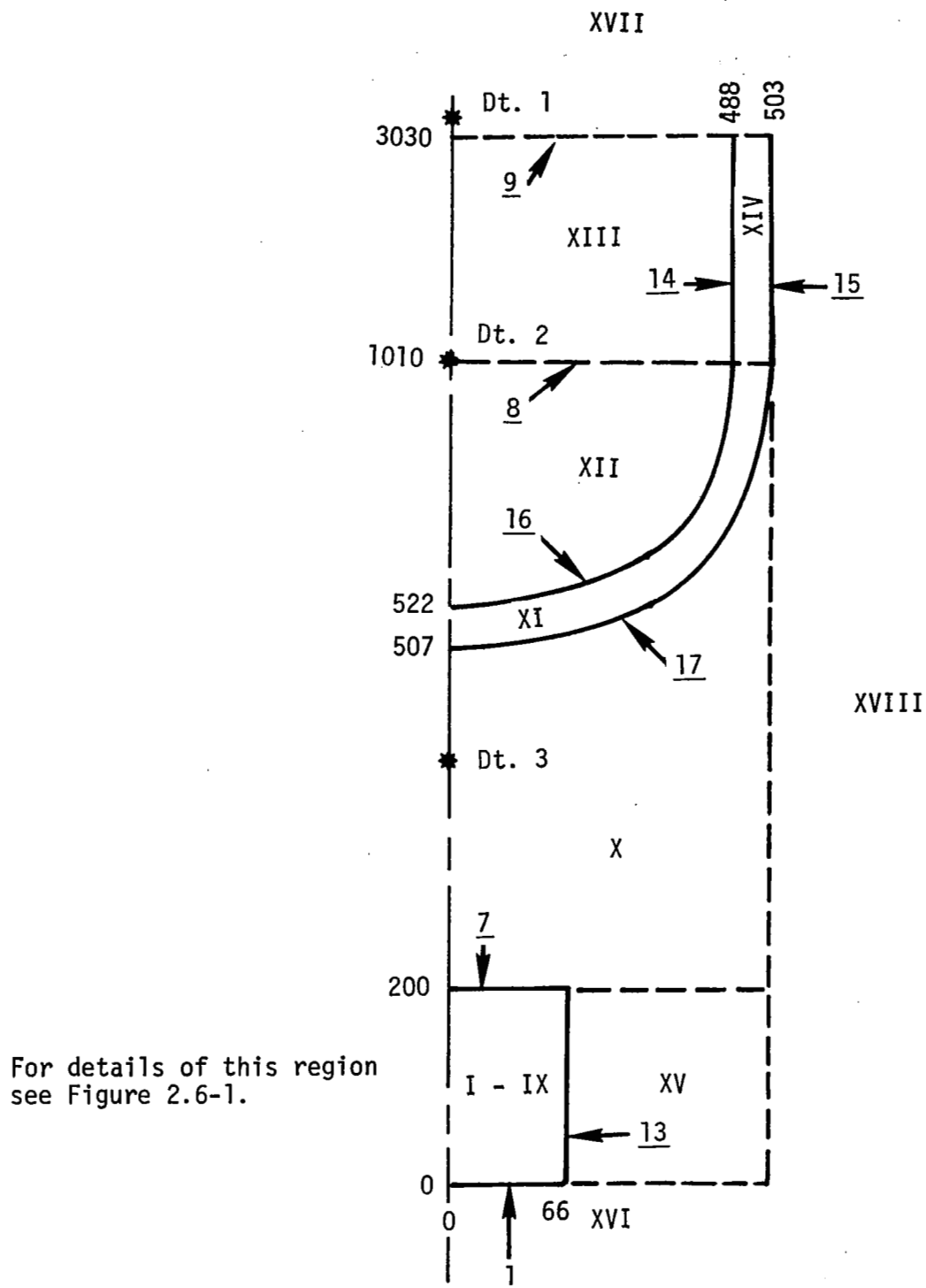


FIGURE 2.6-2 GAMMA RAY SHIELDING GEOMETRY FOR ENGINEERING  
SYSTEM SAMPLE PROBLEM

TABLE 2.6-1 Energy Group Structures

GROUP INDEX	UPPER ENERGY LIMITS, MEV	
	Neutron	Gamma
1	14.9182	10.0
2	0.550232	4.0
3	$4.13994 \times 10^{-7}$	1.0
4	---	0.4
5	---	0.2
	$(1.0 \times 10^{-9})$	$(1.0 \times 10^{-3})$

TABLE 2.6-2 DØT Zone Descriptions

ZONE INDEX	LOCATION OF ZONE BOUNDARIES, CM		MATERIAL	DENSITY, GM/CM <sup>3</sup>
	RADIUS	HEIGHT		
I	(0-50)	(0-135)	Hydrogen	$5.36 \times 10^{-4}$
			Carbon	1.504
			Iron	$1.143 \times 10^{-2}$
			Uranium	$7.31 \times 10^{-2}$
II	(50-64)	(0-135)	Hydrogen	$1.40 \times 10^{-3}$
			Carbon	1.656
III	(64-66)	(0-200)	Aluminum	2.7
IV	(0-64)	(135-140)	Hydrogen	$7.0 \times 10^{-2}$
V	(0-64)	(140-160)	Hydrogen	$4.73 \times 10^{-2}$
			Iron	2.0
VI	(0-55)	(160-175)	Hydrogen	$1.26 \times 10^{-2}$
			Aluminum	2.24
VII	(0-55)	(175-195)	Hydrogen	$7.0 \times 10^{-2}$
VIII	(0-64)	(195-200)	Aluminum	2.7
IX	(55-64)	(160-195)	Hydrogen	$7.0 \times 10^{-2}$

TABLE 2.6-3 Material and Geometry Descriptions,  
Gamma Ray Shielding Sample Problem

Index	Boundary Surface Numbers	Material	Density, gm/cm <sup>3</sup>
I	1,2,10	Hydrogen	$5.36 \times 10^{-4}$
		Carbon	1.504
		Iron	$1.143 \times 10^{-2}$
		Uranium	$7.31 \times 10^{-2}$
II	1,2,10,12	Hydrogen	$1.40 \times 10^{-3}$
		Carbon	1.656
III	1,7,12,13	Aluminum	2.7
IV	2,3,12	Hydrogen	$7.0 \times 10^{-2}$
V	3,4,12	Hydrogen	$4.73 \times 10^{-2}$
		Iron	2.0
VI	4,5,11	Hydrogen	$1.26 \times 10^{-2}$
		Aluminum	2.24
VII	5,6,11	Hydrogen	$7.0 \times 10^{-2}$
VIII	6,7,12	Aluminum	2.7
IX	4,6,11,12	Hydrogen	$7.0 \times 10^{-2}$
X	7,8,15,17	Void	
XI	8,16,17	Aluminum	2.7
XII	8,16	Hydrogen	$7.0 \times 10^{-2}$
XIII	8,9,14	Hydrogen	$7.0 \times 10^{-2}$
XIV	8,9,14,15	Aluminum	2.7
XV	1,7,13,15	Void	
*XVI	1,15	Void (external)	
*XVII	9,15	Void (external)	
*XVIII	15	Void (external)	

\*KAPV ONLY

TABLE 2.6-4 KAPV and FASTER Surface Descriptions

Surface Index	Type	Location			
1	plane	at	Z =	0 cm	
2	"			135	
3	"			140	
4	"			160	
5	"			175	
6	"			195	
7	"			200	
8	"			1010	
9	"			3030	
10	Cylinder	radius	=	50	
11	"			55	
12	"			64	
13	"			66	
14	"			488	
15	"			503	
16	sphere	radius	=	488	at Z = 1010 cm
				503	1010

\$JOB INAP SYSTEM DOT SAMPLE PROBLEM

P\$INPUT

ID=1, ISN=6, IGE=1, IZM=9, IM=11, JM=20, EPS=.001, ILBC=1, MT=11,  
MS=23, MCR=5, IGM=3, IHT=3, IHS=4, ITL=6, IDFS=1, ITMO=1, EPW=.05,  
IZFLX=3, IZMOUT=5, ITII=50, ITMI=50, IENG=3,  
NAFT = 27,

\$END

14\*

C..... MATERIAL NUMBER 1, P 0, TABLE LENGTH 6, 3 GROUPS

C GROUP 1

0 +34548- 9 0 + 0+ 0 0 +26107- 4 0 +15195- 4 2R+ 0+ 0 1

C GROUP 2

0 +11600- 6 0 + 0+ 0 0 +18186- 3 0 +16727- 3 0 +10912- 4 0 + 0+ 0 1

C GROUP 3

0 +16942- 5 0 + 0+ 0 0 +20510- 3 0 +20340- 3 0 +14471- 4 0 +69536-11 1

C..... MATERIAL NUMBER 6, P 0, TABLE LENGTH 6, 3 GROUPS

C GROUP 1

0 +25850- 6 0 + 0+ 0 0 +19635- 4 0 +16974- 4 2R+ 0+ 0 1

C GROUP 2

0 +10544- 8 0 + 0+ 0 0 +48159- 4 0 +47477- 4 0 +24025- 5 0 + 0+ 0 1

C GROUP 3

0 +17359- 7 0 + 0+ 0 0 +48938- 4 0 +48920- 4 0 +68087- 6 0 + 0+ 0 1

C..... MATERIAL NUMBER 13, P 0, TABLE LENGTH 6, 3 GROUPS

C GROUP 1

0 +47980- 6 0 + 0+ 0 0 +27223- 4 0 +24907- 4 2R+ 0+ 0 1

C GROUP 2

0 +10996- 6 0 + 0+ 0 0 +23825- 4 0 +23378- 4 0 +18363- 5 0 + 0+ 0 1

C GROUP 3

0 +12075- 5 0 + 0+ 0 0 +16683- 4 0 +15475- 4 0 +33739- 6 0 + 0+ 0 1

C..... MATERIAL NUMBER 26, P 0, TABLE LENGTH 6, 3 GROUPS

C GROUP 1

0 +21448- 6 0 + 0+ 0 0 +31709- 4 0 +29582- 4 2R+ 0+ 0 1

C GROUP 2

0 +96194- 6 0 + 0+ 0 0 +90642- 4 0 +89416- 4 0 +19123- 5 0 + 0+ 0 1

C GROUP 3

0 +12879- 4 0 + 0+ 0 0 +12080- 3 0 +10792- 3 0 +26494- 6 0 + 0+ 0 1

C..... MATERIAL NUMBER 92, P 0, TABLE LENGTH 6, 3 GROUPS

C GROUP 1  
0 +14193- 4 0.0 0 +71380- 4 0 +49424- 4 2R+ 0+ 0 1

C GROUP 2  
0 +37818- 3 0.0 0 +48867- 3 0 +11041- 3 0 +77637- 5 0 + 0+ 0 1

C GROUP 3  
0 +33124- 2 0.0 0 +34524- 2 0 +14000- 3 0 +80345- 7 0 + 0+ 0 1

T

17\* 5R 1.0 6R 0.0 5R 1.0 6R 0.0 5R 1.0  
6R 0.0 5R 1.0 6R 0.0 5R 1.0 6R 0.0 5R 1.0  
6R 0.0 5R 1.0 6R 0.0 5R 1.0 6R 0.099R 0.0

33R 0.0 T

17\* 5R 2.0 6R 0.0 5R 2.0 6R 0.0 5R 2.0  
6R 0.0 5R 2.0 6R 0.0 5R 2.0 6R 0.0 5R 2.0  
6R 0.0 5R 2.0 6R 0.0 5R 2.0 6R 0.099R 0.0

33R 0.0 T

17\* 5R 3.0 6R 0.0 5R 3.0 6R 0.0 5R 3.0  
6R 0.0 5R 3.0 6R 0.0 5R 3.0 6R 0.0 5R 3.0  
6R 0.0 5R 3.0 6R 0.0 5R 3.0 6R 0.099R 0.0

33R 0.0 T

3\* T

7\* 8--37707954 8--26663550 8- 26663550 8--73181094 8--68150771  
8--26663550 8- 26663550 8- 68150771 8--96379744 8--92618088 8--68150771  
8--26663550 8- 26663550 8- 68150771 8--92618088 8--37707954 8--26663550  
8- 26663550 8--73181094 8--68150771 8--26663550 8- 26663550 8- 68150771  
8--96379744 8--92618088 8--68150771 8--26663550 8- 26663550 8- 68150771  
8- 92618088 8--92618088 8--92618088 8--92618088 8--68150771 8--68150771  
8--68150771 8--68150771 8--68150771 8--26663550 8--26663550 8--26663550  
8--26663550 8--26663550 8--26663550 8--26663550 3R.92618088 5R.68150771  
7R.26663550 T

6\* 0.0 2R.04403156 0.0 4R.03930177 0.0  
.04403156 .03930177 2R.04403156 .03930177 .04403156 0.0  
2R.04403156 0.0 4R.03930177 0.0 .04403156 .03930177  
2R.04403156 .03930177 .04403156 T

4\* 0.0 10.0 20.0 40.0 45.0  
50.0 55.0 60.0 63.0 64.0 65.0

66.0							
2*	0.0	5.0	10.0	20.0	40.0		
80.0	120.0	130.0	135.0	140.0	145.0		
155.0	160.0	165.0	170.0	175.0	180.0		
190.0	195.0	197.5	200.0				
8\$	5R	1 4R	2 2R	3			
	5R	1 4R	2 2R	3			
	5R	1 4R	2 2R	3			
	5R	1 4R	2 2R	3			
	5R	1 4R	2 2R	3			
	5R	1 4R	2 2R	3			
	5R	1 4R	2 2R	3			
	5R	1 4R	2 2R	3			
9R	4 2R	3 9R	5 2R	3 9R	5 2R	3	
9R	5 2R	3 6R	6 3R	9 2R	3 6R	6	
3R	9 2R	3 6R	6 3R	9 2R	3 6R	7	
3R	9 2R	3 6R	7 3R	9 2R	3 6R	7	
3R	9 2R	3 9R	8 2R	3 9R	8 2R	3	
9\$		6	7	8	9	10	
	11	9	8	9			
1*	3R	0.0					
5*	3R	1.0					
10\$	4I	6	11 3I	1	5 4R	6	
2R	7	8	9 2R	10 2R	11		
11\$	11R	0	1	2	4	5	
	1	2	3 2R	1	4	1	
	3						
12*	6R	0.0	.5977	.05016	.02233	.01079	
.002561	5.36	E-4	1.504	1.1429E-2	7.31 E-2	1.40 E-3	
1.656	2.8		7.0 E-2	4.73 E-2	2.0	1.26 E-2	
2.24							
28*	14.9182		.550232	6-.413994	1.0 E-9		
34\$		1	3	5	6	8	
T							

## NAP SAMPLE PROBLEM FOR INAP SYSTEM KAPV-VERSION

5	3						
1.49182E+01	5.50232E-01	4.13994E-07	1.00000E-09				
0.	5.00000E+01	0.	1.35000E+02	1.06029E+06		1	1
3.51341E+01	1.68703E+02	6.26609E+01				1	2
6.40000E+01	6.60000E+01	0.	2.00000E+02	1.63363E+05		3	1
1.42321E+00	5.42432E+00	5.41705E+00				3	2
0.	6.40000E+01	1.40000E+02	1.60000E+02	2.57359E+05		5	1
2.09306E+00	2.35381E+00	9.27434E+00				5	2
0.	5.50000E+01	1.60000E+02	1.75000E+02	1.42550E+05		6	1
3.13183E-01	4.63476E-01	1.47054E+00				6	2
0.	6.40000E+01	1.95000E+02	2.00000E+02	6.43398E+04		8	1
7.11765E-03	5.11024E-03	4.13477E-02				8	2

107

[illegible]

13	27		1	6.024	E-2					
	1	9		3	3					
	2	4		6	8	10	10	10	10	10
			1	68.5		0.0				
26	58		1	6.855	E-5					
	1	6		3	3					
	2	4		6	8	10	10			
			1	68.5		0.0				
13	27		1	5.0	E-2					
	3	9		2	3					
	2	4		6	8	10	10	10	10	10
			1	68.5		0.0				
13	27		1	6.024	E-2					
LAST										

ALPHAN

```

15      1 INAP SYSTEM TEST PROBLEM KAPV
15      46 SOURCE REGION CALCULATION RESULTS
15      76 SUBTOTAL RESULTS
15     106 SUMMATION OVER ALL REGIONS
   3     136 GAM RESP 1
   3     226 DET PT. 1
   3     229 DET PT. 2
   3     232 DET PT. 3
15     401 DOSE CALCULATION

```

INTEGE

[illegible]

4	554	7	8	15	17
4	1154	8	13	18	11
3	560	8	16	17	
3	1160	14	12	10	
2	566	8	16		
2	1166	13	11		
3	572	8	9	14	
3	1172	12	17	14	
4	578	8	9	14	15
4	1178	11	17	13	18
4	584	1	7	13	15
4	1184	16	10	3	18
2	590	1	15		
2	1190	1	18		
2	596	9	15		
2	1196	13	18		
1	602	15			
1	1202	10			

## FLOAT I

2	1475	1.0	1.0			
2	1575	1.0	1.0			
2	1675	1.0	1.0			
2	1975	1010.0	1010.0			
5	2060	0.0	135.0	140.0	160.0	175.0
5	2065	195.0	200.0	1010.0	3030.0	50.0
5	2070	55.0	64.0	66.0	488.0	503.0
2	2075	488.0	503.0			
3	2160	1.0	1.0	1.0		
3	2163	51.0	0.0	1.0		
3	2166	65.0	0.0	1.0		
3	2169	1.0	1.0	136.0		
3	2172	1.0	1.0	141.0		
3	2175	1.0	1.0	161.0		
3	2178	1.0	1.0	176.0		
3	2181	1.0	1.0	196.0		
3	2184	56.0	0.0	161.0		

3	2187	1.0	1.0	201.0				
3	2190	1.0	1.0	508.0				
3	2193	1.0	1.0	523.0				
3	2196	1.0	1.0	1011.0				
3	2199	489.0	0.0	1011.0				
3	2202	67.0	0.0	1.0				
3	2205	1.0	1.0	-1.0				
3	2208	1.0	1.0	3031.0				
3	2211	504.0	0.0	1.0				
5	2460	5.36	E-4 1.504	0.0	1.1429	E-2	7.31	E-2
5	2480	1.4	E-3 1.656	0.0	0.0		0.0	
5	2500	0.0	0.0	2.7	0.0		0.0	
5	2520	7.0	E-2 0.0	0.0	0.0		0.0	
5	2540	4.73	E-2 0.0	0.0	2.0		0.0	
5	2560	1.26	E-2 0.0	2.24	0.0		0.0	
5	2580	0.0	0.0	1.0	E-30 0.0		0.0	
5	4750	1.0	1.0	1.0	1.0		1.0	
3	5360	0.0	3035.0	0.0				
3	5363	0.0	1011.0	0.0				
3	5366	0.0	400.0	0.0				
5	5131	.0	6.0	13.0	26.0		92.0	

INTEGE

1	1	5			
1	20	1			
3	26	1	1	1	

FLOATI

1	1	1.00000E+00				
5	3560	7.00000E+00	2.50000E+00	7.00000E-01	3.00000E-01	1.00500E-01

FLOATI

2	5661	0.	7.50000E+00		
---	------	----	-------------	--	--

INTEGE

1	25	1		
1	29	3		
1	31	-1		

2	50	5	8				
5	52	4	6	8	10	12	
FLOAT I							
2	49	0.			3.14159E+00		
5	7	0.			1.00000E+01	2.00000E+01	3.00000E+01 4.00000E+01
1	12	5.00000E+01					
5	28	0.			1.68750E+01	3.37500E+01	5.06250E+01 6.75000E+01
4	33	8.43750E+01			1.01250E+02	1.18125E+02	1.35000E+02
5	1400	0.			4.83265E-07	3.33541E-07	8.90862E-04 5.73688E-02

LAST		
INTEGE		
1	25	2
1	29	3
1	31	1
2	50	2 20
2	52	6 8

FLOAT I							
2	49	0.			3.14159E+00		
3	7	6.40000E+01			6.50000E+01	6.60000E+01	
5	28	0.			1.00000E+01	2.00000E+01	3.00000E+01 4.00000E+01
5	33	5.00000E+01			6.00000E+01	7.00000E+01	8.00000E+01 9.00000E+01
5	38	1.00000E+02			1.10000E+02	1.20000E+02	1.30000E+02 1.40000E+02
5	43	1.50000E+02			1.60000E+02	1.70000E+02	1.80000E+02 1.90000E+02
1	48	2.00000E+02					
5	1400	0.			1.92877E-01	2.06132E-03	0. 2.06132E-05

LAST		
INTEGE		
1	25	3
1	29	3
1	31	1
2	50	9 3
9	52	2 4 6 8 10 10 10 10 10

FLOAT I							
2	49	0.			3.14159E+00		
5	7	0.			7.11111E+00	1.42222E+01	2.13333E+01 2.84444E+01
5	12	3.55556E+01			4.26667E+01	4.97778E+01	5.68889E+01 6.40000E+01

```

4      28 1.40000E+02 1.46667E+02 1.53333E+02 1.60000E+02
5      1400 0.      1.14878E-05 0.      0.      3.44635E-07
LAST
INTEGE
1      25 4
1      29 3
1      31 1
2      50 6 3
6      52 2 4 6 8 10 10
FLOATI
2      49 0.      3.14159E+00
5      7 0.      9.16667E+00 1.83333E+01 2.75000E+01 3.66667E+01
2      12 4.58333E+01 5.50000E+01
4      28 1.60000E+02 1.65000E+02 1.70000E+02 1.75000E+02
5      1400 0.      4.22695E-02 3.75341E-04 0.      3.75341E-06
LAST
INTEGE
1      25 5
1      29 3
1      31 3
2      50 9 2
9      52 2 4 6 8 10 10 10 10 10
FLOATI
2      49 0.      3.14159E+00
5      7 0.      7.11111E+00 1.42222E+01 2.13333E+01 2.84444E+01
5      12 3.55556E+01 4.26667E+01 4.97778E+01 5.68889E+01 6.40000E+01
3      28 1.95000E+02 1.97500E+02 2.00000E+02
5      1400 0.      1.42033E-03 1.02733E-05 0.      1.02733E-07
LAST
FLOATI
2      5661 7.50000E+00 6.50000E+02
INTEGE
1      25 1
1      29 3
1      31 -1
2      50 5 8

```

5	52	4	6	8	10	12					
FLOATI											
2	49	0.				3.14159E+00					
5	7	0.				1.00000E+01	2.00000E+01	3.00000E+01	4.00000E+01		
1	12	5.00000E+01									
5	28	0.				1.68750E+01	3.37500E+01	5.06250E+01	6.75000E+01		
4	33	8.43750E+01				1.01250E+02	1.18125E+02	1.35000E+02			
5	1400	0.				3.62996E-05	1.03711E-05	1.12385E-02	5.60698E-02		
LAST											
INTEGE											
1	25	2									
1	29	3									
1	31	1									
2	50	2	20								
2	52	6	8								
FLOATI											
2	49	0.				3.14159E+00					
3	7	6.40000E+01				6.50000E+01	6.60000E+01				
5	28	0.				1.00000E+01	2.00000E+01	3.00000E+01	4.00000E+01		
5	33	5.00000E+01				6.00000E+01	7.00000E+01	8.00000E+01	9.00000E+01		
5	38	1.00000E+02				1.10000E+02	1.20000E+02	1.30000E+02	1.40000E+02		
5	43	1.50000E+02				1.60000E+02	1.70000E+02	1.80000E+02	1.90000E+02		
1	48	2.00000E+02									
5	1400	0.				1.21404E-03	1.11223E-15	0.		1.11223E-17	
LAST											
INTEGE											
1	25	3									
1	29	3									
1	31	1									
2	50	9	3								
9	52	2	4	6	8	10	10	10	10	10	
FLOATI											
2	49	0.				3.14159E+00					
5	7	0.				7.11111E+00	1.42222E+01	2.13333E+01	2.84444E+01		
5	12	3.55556E+01				4.26667E+01	4.97778E+01	5.68889E+01	6.40000E+01		
4	28	1.40000E+02				1.46667E+02	1.53333E+02	1.60000E+02			

```

5      1400 0.      8.62887E-04 0.      0.      2.58866E-05
LAST
INTEGE
1      25  4
1      29  3
1      31  1
2      50  6  3
6      52  2  4  6  8 10 10
FLOATI
2      49 0.      3.14159E+00
5      7 0.      9.16667E+00 1.83333E+01 2.75000E+01 3.66667E+01
2      12 4.58333E+01 5.50000E+01
4      28 1.60000E+02 1.65000E+02 1.70000E+02 1.75000E+02
5      1400 0.      2.21062E-04 2.02523E-16 0.      2.02523E-18
LAST
INTEGE
1      25  5
1      29  3
1      31  3
2      50  9  2
9      52  2  4  6  8 10 10 10 10 10
FLOATI
2      49 0.      3.14159E+00
5      7 0.      7.11111E+00 1.42222E+01 2.13333E+01 2.84444E+01
5      12 3.55556E+01 4.26667E+01 4.97778E+01 5.68889E+01 6.40000E+01
3      28 1.95000E+02 1.97500E+02 2.00000E+02
5      1400 0.      6.05060E-06 5.54317E-18 0.      5.54317E-20
LAST
END

```

CUMULATIVE TIME RESULTS FOR ALL SOURCE REGIONS TO REGION 5  
 TO TIME 6.500E+02 HRS

DOSE CALCULATION

RECIEVER POINT DET PT. 2  
 COORDINATES R..... 0.

Z..... 1.01100E+03 PHI..... 0.

		GAM RESP 1
1	7.00	0.
2	2.50	2.262E-08
3	.70	2.427E-10
4	.30	1.088E-09
5	.10	1.018E-08
		-----
		3.414E-08

DOSE CALCULATION

RECIEVER POINT DET PT. 2  
 COORDINATES R..... 0.

Z..... 1.01100E+03 PHI..... 0.

		GAM RESP 1
1	7.00	0.
2	2.50	2.089E-08
3	.70	2.445E-10
4	.30	1.088E-09
5	.10	1.018E-08
		-----
		3.241E-08

### 3.0 ACCURATE SYSTEM

#### 3.1 Introduction

An accurate code system is one in which the individual codes are not limited in the precision of the desired answer except by those limitations imposed by computer storage and cost. This requires that an accurate system treat complex three-dimensional geometry with a numerical approximation to the particle transport equation that is theoretically capable of exactly reproducing the differential or integral form of the transport equation when not limited by finite computer capabilities. Only the Monte Carlo method satisfies both requirements of the accurate system. Therefore, for both the neutron transport and the gamma ray shielding modules of the accurate systems, it was necessary to utilize Monte Carlo transport codes. It was also found to be advantageous to utilize the same Monte Carlo code for both the neutron transport and gamma ray shielding modules to reduce the amount of input data that must be prepared by the user.

The FASTER Monte Carlo Transport Program is used for both the neutron transport and gamma ray shielding modules of the Accurate INAP System while the NAP Code is used for the activation and decay chain module. It was necessary to rearrange the order of the source input to the FASTER program to facilitate the system operation. The data block containing the source description was moved to the end of the input deck to avoid requiring the user to collate and combine input decks to set up the gamma ray shielding problem. The input data format remains unchanged.

In the following sections the input and output of each of the component programs are described in detail in Sections 3.2 and 3.3 and the overall operation of the code system is discussed in Section 3.4. Finally, in Section 3.5 a sample problem for the code system is presented.

#### 3.2 Neutron Transport and Gamma Ray Shielding Module

##### 3.2.1 Operating Instructions

The version of FASTER utilized for the INAP System is essentially unchanged from that available from RSIC and reported in Reference 10. For details of the program logic, numerical methods, operating instructions and interpretation of input/output variables the user should consult this

reference. In the following paragraphs, the modifications to the program will be described and instructions for its use in the INAP System will be presented.

The use of the same program for both the neutron transport and gamma ray shielding functions significantly reduces the amount of data which must be prepared by the INAP user since the geometry and the material composition data and some of the biasing options will remain unchanged when performing the neutron and gamma ray problems.

Basically, the major modification to the FASTER program is the order in which the source input cards are read. More specifically, the original FASTER required these cards to be read as the third group of input data which required that a majority of the data be repeated to run multiple cases. In the INAP System this meant that most of the card input would have to be repeated for each time for which the cumulative dose was desired. Hence, by altering the calling sequence, the input requirements have been greatly reduced for the INAP System. This alteration did require shifting the order in which the gamma energy group structure is read. This data is now read with the cross section cards. The additional variables relating to the times at which the dose rate or cumulative dose is desired have been added to the source input section.

A minor modification of FASTER was necessary to output on cards those quantities required by NAP as input and to print out the times of the dose and dose rate calculations.

The logical files used by FASTER are TAPE5, TAPE6, and TAPE7. TAPE5 is the data input file; TAPE6 is the printed output file; and TAPE7 is the punched output file. The INAP version of FASTER may be used independent of the INAP System if so desired by defining TAPE7 as a scratch file to eliminate the punched card output. None of the modifications incorporated into the code alter the functions and capabilities described in Reference 10.

Compatibility with other computer facilities can be obtained by the following changes in the control program in the first routine.

- a) Change of input tape logical designation from 5 to i  
replace M1 = 5 by M1 = i
- b) Change of output tape logical designation from 6 to j  
replace M2 = 6 by M2 = j

- c) Change of punch tape logical designation from 7 to m  
replace  $M3 = 7$  to  $M3 = m$
- d) Change of maximum number of lines per printout page from 40 to k  
replace  $LINEX = 40$  by  $LINEX = k$
- e) Change of maximum number of locations for dimensioned arrays  
from 4000 to 1  
replace  $COMMON\ H(4000)$  by  $COMMON\ H(1)$   
and replace  $NSTORE = 3001$  by  $NSTORE = J + 1$  where  $0 \leq J \leq 1+1$ ,  
replace  $IFXXT = 3002$  by  $IFXXT = J+2$   
and replace  $NTØX = 4000$  by  $NTØX = 1$

Presently the random number generator is a FØRTRAN routine of limited size and is used only to generate numbers consistent with the sample problems. Once the sample problem is successfully run a more extensive random number routine should be used.

### 3.2.2 Input Description

The following paragraphs provide a complete description of the input requirements of the INAP version of the FASTER program for both neutron transport and gamma ray shielding calculations. Since the ordering of the card input has been modified, this input description supercedes that given in Reference 10.

#### Input Formats

The FASTER program utilizes standard FØRTRAN input statements. A variety of formats are used, however, each format utilizes various combinations of the following data fields:

hollerith information: A4 field (4 columns)  
integer data: I3 field (3 columns)  
floating point data: E9.0 field (9 columns)

Note that for floating point data entered without a decimal point, the decimal point is assumed to be to the right of the data field.

In preparing data, it should be remembered that all blanks in integer or floating point fields are interpreted as zeros. Therefore, all integers (including exponents of floating point numbers) must be right justified in the field.

## Card Input and Output

Each physical data card is written on the output file as soon as it is read from the input file. The resulting printout includes the information in card columns (cc) 73 through 80 of the data cards. Since the present version of FASTER does not print details of problem data except for the input cards, prolific use of card labeling is desirable. A note of warning: in obtaining the card identification from cc 73-80, all unused data fields in cc 1-72 are interpreted as data and these unused fields should be blank or contain valid data punches.

## Input Data Sections

Data input to the INAP version of FASTER is divided like the original RSIC version of FASTER, however, the order of the input has been changed to simplify the handling of dose and dose rate source data changes required by the gamma ray calculation. The first data card of each input section is the minimum input requirement. The six sections of data input are:

1) title cards, limits, and options; 2) surfaces and regions; 3) cross sections; 4) flux groups, response functions and detectors; 5) sampling parameters; and 6) fixed sources.

Input section six is repeated as often as necessary to specify the source dependencies. Detailed input instructions are given below.

## Input Control Procedure

The first data card of each input section contains integer constants controlling the input of the remainder of the data in the section. The general procedure is

input control constant  $\leq 0$ , no input

input control constant  $> 0$ , input

When input is present, the control constant may serve a dual purpose by also denoting the quantity of input. As an example, the first input-control constant (IN1) for each data section pertains to hollerity or comment cards. If non-positive ( $IN1 \leq 0$ ), no comment cards should be supplied. If desired, any number of comment cards (up to 999) may be inserted immediately after the input control card for each section. The value of the first input control constant is then set equal to the number of these comment cards, i.e.,  $IN1 = \text{total number of comment cards}$ .

# SECTION 1 DATA; TITLE CARDS, LIMITS AND OPTIONS

## CARD 1-0, Input Controls for Section 1 Data

NOTE: This card is always required.

<u>COLUMN</u>	<u>FORMAT</u>	<u>SYMBOL</u>	<u>DEFINITION</u>
1-3	I3	IN1	input control for card 1-1 (descriptive cards) omit card 1-1 if $IN1 \leq 0$ supply IN1 physical cards if $IN1 \geq 1$
4-6	I3	IN2	input control for card 1-2 (first title card) omit card 1-2 if $IN2 \leq 0$ supply card 1-2 if $IN2 \geq 1$
7-9	I3	IN3	input control for card 1-3 (second title card) omit card 1-3 if $IN3 \leq 0$ supply card 1-3 if $IN3 \geq 1$
10-12	I3	IN4	input control for card 1-4 (geometric limits) omit card 1-4 if $IN4 \leq 0$ supply card 1-4 if $IN4 \geq 1$
13-15	I3	IN5	input control for card 1-5 (fixed source limits) omit card 1-5 if $IN5 \leq 0$ supply card 1-5 if $IN5 \geq 1$
16-18	I3	IN6	input control for card 1-6 (cross section limits) omit card 1-6 if $IN6 \leq 0$ supply card 1-6 if $IN6 \geq 1$
19-21	I3	IN7	input control for card 1-7 (neutron scattering limits) omit card 1-7 if $IN7 \leq 0$ supply card 1-7 if $IN7 \geq 1$
22-24	I3	IN8	input control for card 1-8 (flux limits) omit card 1-8 if $IN8 \leq 0$ supply card 1-8 if $IN8 \geq 1$
25-27	I3	IN9	input control for card 1-9 (sampling options) omit card 1-9 if $IN9 \leq 0$ supply card 1-9 if $IN9 \geq 1$
28-30	I3	IN10	input control for card 1-10 (iteration limits) omit card 1-10 if $IN10 \leq 0$ supply card 1-10 if $IN10 \geq 1$

<u>COLUMN</u>	<u>FORMAT</u>	<u>SYMBOL</u>	<u>DEFINITION</u>
31-33	13	IN11	printout control for storage map printout no printout of storage map if $IN11 \leq 0$ printout of storage map if $IN11 \geq 1$
34-72	1313	---	these columns are not used and should be left blank
73-80	2A4	---	any desired information for card identification

#### CARD 1-1, Descriptive Information for Section 1 Data

NOTE: a) Omit this card if  $IN1 \leq 0$   
b) Supply IN1 physical cards if  $IN1 \geq 1$

1-72	18A4	---	any desired information
73-80	2A4	---	any desired information for card identification

#### CARD 1-2, First Title Card for Labeling the Printout

NOTE: a) Omit this card if  $IN2 \leq 0$   
b) Supply this card if  $IN2 \geq 1$

1-72	18A4	---	any desired information for identification of the problem; this will then appear on the first line of each printout page
73-80	2A4	---	any desired information for card identification

#### CARD 1-3, Second Title Card for Labeling the Printout

NOTE: a) Omit this card if  $IN3 \leq 0$   
b) Supply this card if  $IN3 \geq 1$

1-72	18A4	---	any desired information for identification of the problem; this will appear on the second line of each printout page
73-80	2A4	---	any desired information for card identification

#### CARD 1-4, Geometric Limits

NOTE: a) Omit this card if  $IN4 \leq 0$   
b) Supply this card if  $IN4 \geq 1$

<u>COLUMN</u>	<u>FORMAT</u>	<u>SYMBOL</u>	<u>DEFINITION</u>
1-3	I3	NSMAX	total number of surfaces required for the geometry description
4-6	I3	NAMAX	maximum number of coefficients required to define each surface in the <u>expanded</u> form, e.g. NAMAX=6 for geometries involving any cones or spheres
7-9	I3	NRMAX	total number of regions required to describe the material distribution including voids
10-12	I3	NBMAX	maximum number of surfaces bounding a region
13-15	I3	NSTMAX	maximum number of regions which can be traversed by a single straight line or ray; the theoretical limit is $2 \cdot \text{NSMAX} - (\text{number plane surfaces} + 1)$
16-72	19I3	---	these columns are not used and should be left blank
73-80	2A4	---	any desired information for card identification

#### CARD 1-5, Fixed Source Limits

- NOTE: a) Omit this card if  $\text{IN5} \leq 0$   
b) Supply this card if  $\text{IN5} \geq 1$

1-3	I3	NEMAX	number of energy groups used in this problem for source spectra and cross sections; source spectra may be described in a different group structure and are regrouped as noted later
4-6	I3	NVMAX	total number of fixed sources
7-9	I3	NXMAX	maximum number of points used to tabulate each spatial or angular source distribution
10-12	I3	NXEMAX	maximum number of energy points required to tabulate the differential source spectrum; if any source spectra are described by group integrated values, 2 energy points will be generated for each of these groups before the spectrum is integrated into the group structure for the problem.

<u>COLUMN</u>	<u>FORMAT</u>	<u>SYMBOL</u>	<u>DEFINITION</u>
13-72	2013	---	these columns are not used and should be left blank
73-80	2A4	---	any desired information for card identification

#### CARD 1-6, Basic Cross Section Limits and Options

- NOTE: a) Omit this card if  $IN6 \leq 0$   
b) Supply this card if  $IN6 \geq 1$

1-3	13	NXSECT	particle type option. 0 for photons. 1 for neutrons
4-6	13	NUNITD	composition units option. 0 for $10^{24}$ atoms/cm <sup>3</sup>
7-9	13	NUNITX	microscopic cross sections units option. 0 for barns/atom. 1 for cm <sup>2</sup> /gm
10-12	13	NIMAX	total number of different elements or isotopes
13-15	13	NMMAX	total number of composite materials; hydrogen densities can be entered by region thus reducing the total number of different compositions, e.g. pure hydrogen compositions need not be defined
16-72	1913	---	these columns are not used and should be left blank
73-80	2A4	---	any desired information for card identification

#### CARD 1-7, Neutron Scattering Limits

- NOTE: a) Omit this card if  $IN7 \leq 0$ .  
b) Supply this card if  $IN7 \geq 1$ .  
c) For photon problems, define each variable on this card as zero.

1-3	13	NØRDER	maximum number of elastic scattering transfer matrices for all elements. 1 for $P_0$ (transport approximation) (see notes after card 4-5 for internal cross section juggling) 2 for $P_1$ , 3 for $P_2$ , etc. Negative fluxes can, and will, occur for $NØRDER > 1$ and deep penetrations
-----	----	--------	---

<u>COLUMN</u>	<u>FORMAT</u>	<u>SYMBOL</u>	<u>DEFINITION</u>
4-6	I3	NDØWN	maximum group-to-group transfer for elastic scattering for all elements. 1 for in group only, 2 for down 1, etc.
7-9	I3	NELAS	maximum number of groups for which non-elastic transfer can be initiated for all elements. 0 indicates none if these cross sections are included in the $P_0$ transfer
10-12	I3	NDØWN	maximum group-to-group transfer for non-elastic scattering for all elements. 1 for in group only, 2 for down 1, etc.
13-72	20I3	---	these columns are not used and should be left blank
73-80	2A4	---	any desired information for card identification

CARD 1-8, Flux Limits

NOTE: a) Omit this card if  $IN8 \leq 0$ .  
b) Supply this card if  $IN8 \geq 1$ .

1-3	I3	NGMAX	number of flux groups; less than or equal to the number of groups used for source spectra and cross sections
4-6	I3	NFMAX	total number of response functions such as flux-to-dose, energy deposition. 0 indicates no response functions
7-9	I3	NVMØD	total number of fixed sources for which separate flux contributions are desired. 0 indicates none
10-12	I3	NCMAX	number of separate contributions to the flux by order-of-scatter 0-none, 1-uncollided flux, 2-uncollided flux and single scattered flux, etc.
13-15	I3	NIMAX	number of Legendre moments of the angular flux 0, $P_0$ moment (always obtained, $\equiv$ scalar flux) 1, $P_0$ and $P_1$ moments, etc.

<u>COLUMN</u>	<u>FORMAT</u>	<u>SYMBOL</u>	<u>DEFINITION</u>
16-18	13	NTMAX	number of length-of-flight moments of the flux. 0, zeroth moment (always obtained, $\equiv$ scalar flux). 1, zeroth and first moments, etc.
19-21	13	NSRMAX	number of regions for which separate scattering contributions are desired
25-72	1613	---	these columns are not used and should be left blank
73-80	2A4	---	any desired information for card identification

#### CARD 1-9, Random Sampling Options

- NOTE: a) Omit this card if  $IN9 \leq 0$ .  
b) Supply this card if  $IN9 \geq 1$ .  
c) The preferred value of each number on this card is 1.

1-3	13	NPØINT	0, calculate fluxes for all detectors simultaneously; the preferred point is defined by input, point detectors must be in void regions. 1, calculate fluxes for each point detector individually; the preferred point(s) is the point detector - surface and volume detectors are ignored
4-6	13	MØDELP	0, randomly select the fixed source and then randomly select the spatial source variables in the source coordinate system. 1, randomly select the spatial source variables in a spherical coordinate system centered at the preferred point; all sources must be volumetric; source volumes must completely cover one or more regions.
7-9	13	MØDELQ	0, randomly select angular source variables in the source coordinate system. 1, randomly select angular source variables like MODELV below, with the direction-before-scattering defined as a unit vector from the center of all sources to the selected source point; all sources must be angular or isotropic.
10-12	13	MØDELU	distance between scatters random selection option. 0, exponential transformation. 1, curve fit of optimum function (difficulties may be encountered for large volumes since the curve fit is from boundary to boundary)

<u>COLUMN</u>	<u>FORMAT</u>	<u>SYMBOL</u>	<u>DEFINITION</u>
13-15	I3	MØDELV	direction vector random selection option. 0, polar angle measured from direction before scattering; azimuthal angle measured from a unit direction vector towards the preferred point. 1, opposite of the above. 2 and 3, polar angle measured from unit vector towards preferred point with combined importance parameters from equations 7.42 and 7.45, or 7.41 and 7.45, respectively; azimuthal angles equiprobable
16-72	19I3	---	these columns are not used and should be left blank
73-80	2A4	---	any desired information for card identification

CARD 1-10, Iteration Limits

NOTE: a) Omit this card if  $INIO \leq 0$ .  
b) Supply this card if  $INIO \geq 1$ .

1-3	I3	NPRINT	total number of printouts during the flux calculations; yields a convergence history and protects against complete loss if the problem is terminated
4-6	I3	NUNITS	number of outer iterations between printouts, i.e., the number of packets of particles
7-9	I3	NUMBER	number of discrete directions obtained by random sampling used in integrating the angular point sources to obtain surface and volume averaged fluxes; not used in NPOINT=1, or if all detectors are points
10-12	I3	KALIDE	maximum number of inner iterations per outer iteration, i.e., the number of collisions per packet
13-72	20I3	---	these columns are not used and should be left blank
73-78	2A4	---	any desired information for card identification

## SECTION 2 DATA; SURFACES AND REGIONS

### CARD 2-0, Input Controls for Section 2 Data

NOTE: a) This card is always required.

<u>COLUMN</u>	<u>FORMAT</u>	<u>SYMBOL</u>	<u>DEFINITION</u>
1-3	13	IN1	input control for Card 2-1 (descriptive cards) omit Card 2-1 if $IN1 \leq 0$ supply IN1 physical cards if $IN1 \geq 1$
	13	IN2	input control for Card 2-2 (surfaces) omit Card 2-2 if $IN2 \leq 0$ . supply IN2 physical cards if $IN2 \geq 1$ , i.e., IN2 surfaces will be described
7-9	13	IN3	input control for Card 2-3 (regions) omit Card 2-3 if $IN3 \leq 0$ . supply IN3 physical cards if $IN3 \geq 1$ , i.e., IN3 regions will be described
10-12	13	IN4 <sup>(1)</sup>	ambiguity index calculation option. 0, do not calculate ambiguity indices. 1, calculate ambiguity indices. Use $IN4=1$ on the first problem
13-15	13	IN5 <sup>(1)</sup>	geometry consistency check option. 0, do not check geometry. 1, check geometry use $IN5=1$ on the first problem
16-72	1913	---	these columns are not used and should be left blank
73-80	2A4	---	any desired information for card identification

### CARD 2-1, Description of Section 2 Data

NOTE: a) Omit this card if  $IN1 \leq 0$ .  
b) Supply IN1 physical cards if  $\geq IN1$  1.

1-72	18A5	---	any desired information for description of the input data
73-80	2A5	---	any desired information for card identification

<sup>(1)</sup>  $IN4=IN5=0$  permits the redefinition of regions by surface description change only. Extreme caution should be used to ensure that the ambiguity indices, calculated in previous problems, are still correct.

<u>COLUMN</u>	<u>FORMAT</u>	<u>SYMBOL</u>	<u>DEFINITION</u>
<u>CARD 2-2, Surface Description</u>			
NOTE: a) Omit this card if $IN2 \leq 0$ b) Supply $IN2$ physical cards if $IN2 \geq 1$ .			
1-3	I3	I	index of the surface being described
4-6	I3	NTP (I)	index(i) of the last non-zero coefficient if the surface is in the expanded form; calculated internally for all other surfaces
7-9	I3	NEX	form ( $n_x$ ) of the surface as input. 0, already in expanded form. 1, NEX I3, special form as indicated in figures 7, 8, and 9 and table 1
10-18	E9.0	AA(1)	first parameter defining the surface
19-27	E9.0	AA(2)	second parameter defining the surface
64-72	E9.0	AA(7)	seventh parameter defining the surface
73-80	2A4	---	any desired information for card identification

CARD 2-2', Description of Section 2 Data

NOTE: a) Supply this card as required to finish the description of a surface, omit otherwise.			
1-9	E9.0	A(8,1)	coefficient of xy in the general surface equation
10-18	E9.0	A(8,1)	coefficient of yz in the general surface equation
19-27	E9.0	A(9,1)	coefficient of zx in the general surface equation
28-72	5E9.0	---	these columns are not used and should be left blank
73-80	2A4	---	any desired information for card identification

---

The requisite parameters are listed in the last column of table 1 and are input in the order shown. If the surface is in the expanded form and rotational terms are involved, supply these on Card 2-2' before supplying Card 2-2 for the next input surface.

<u>COLUMN</u>	<u>FORMAT</u>	<u>SYMBOL</u>	<u>DEFINITION</u>
<u>CARD 2-3, Region Description</u>			
NOTE: a) Omit this card if $IN3 \leq 0$ . b) Supply $IN3$ physical cards if $IN3 \geq 1$ .			
1-3	I3	I	index of the region being described
4-6	I3	ISV(I)	index of the volume source superimposed over this region. 0, indicates none. Required if an only if MODEL $P=1$ . May also be input or changed on Card 6-5
7-9	I3	MTL(I)	>0, index of the composition for the region =0, the region contains hydrogen only. <0, the region is void. This index can be nput or changed on Card 3-9.
10-12	I3	NS(1, I)	first boundary surface index
13-15	I3	NS(2, I)	second boundary surface index. 0 or blank if all boundaries have been listed.
	I3	NS(J, I)	Jth boundary surface index. 0 or blank if all boundaries have been listed.
34-36	I3	NS(9, I)	>0, ninth boundary surface index if the region has exactly nine boundaries. 0, or blank if all boundaries have been listed (less than nine boundaries). -1, if the region has more than nine boundaries; the ninth and remaining boundaries are listed on Card 2-3'.
37-45	E9.0	RHO(I)	hydrogen density in the region apart from that specified for the composite material in the region; units according to NUNITD, may be input or changed on Card 3-10.
46-54	E9.0	XR(1, I)	x-coordinate of any point in the region (cm)
55-63	E9.0	XR(2, I)	y-coordinate of the point in the region (cm)
64-72	E9.0	XR(3, I)	z-coordinate of the point in the region (cm)
73-80	2A4	---	any desired information for card identification

<u>COLUMN</u>	<u>FORMAT</u>	<u>SYMBOL</u>	<u>DEFINITION</u>
---------------	---------------	---------------	-------------------

CARD 2-3', Additional Region Boundaries

- NOTE: a) Supply this card(s) for each region having more than nine boundaries, immediately behind Card 2-3 for the region, omit otherwise.  
 b) This card contains data up to and including the maximum number of boundaries (more than 1 physical card if NBMAX>32).

1-72	2413	NS(1,1)	ninth boundary surface index
		NS(10,1)	tenth boundary surface index
		NS(11,1)	eleventh boundary surface index. 0 or blank if all boundaries are listed
		NS(NBMAX,1)	maximum boundary surface index. 0 or blank if all boundaries are listed
73-80	2A4	---	Any desired information for card identification

# SECTION 3 DATA; MICROSCOPIC CROSS SECTIONS

## CARD 3-0, Input Controls for Section 3 Data

NOTE: a) This card is always required.

<u>COLUMN</u>	<u>FORMAT</u>	<u>SYMBOL</u>	<u>DEFINITION</u>
1-3	I3	IN1	input control for Card 3-1 (descriptive cards) omit Card 3-1 if $IN1 \leq 0$ . supply IN1 physical cards if $IN1 \geq 1$
4-6	I3	IN2	input control for Card 3-2(neutron scattered energies) omit Card 3-3 if $IN2 \leq 0$ supply Card 3-3 if $IN2 \geq 1$
7-9	I3	IN3	input control for microscopic cross sections; omit Cards 3-4 through 3-8 as required if $IN3 \geq 1$
10-12	I3	IN4	input control for Card 3-9 (material-in-region) omit Card 3-9 if $IN4 \leq 0$ supply Card 3-9 with IN4 material-in-region indices if $IN4 \geq 1$
13-15	I3	IN5	input control for Card 3-10 (hydrogen in region) omit Card 3-10 if $IN5 \leq 0$ supply card 3-10 with IN5 hydrogen-in-region densities if $IN5 \geq 1$
16-18	I3	IN6	cross section output option (used only if $IN3 \geq 1$ ), no output if $IN6 \leq 0$ if $IN6 \geq 1$ , total cross sections are printed by group (neutrons) or level (photons) and by material. Heating responses are printed by energy level for each element in (Mev/atom/unit number flux) $\times 10^{24}$ and then for each composite material in (Mev/cm <sup>3</sup> /unit number flux)
19-21	I3	IN7	input control for Card 3-2 (energy levels). omit Card 3-2 if $IN2 \leq 0$ supply card 3-2 if $IN2 \geq 1$
19-72	17I3	---	these columns are not used and should be left blank
73-80	2A4	---	any desired information for card identification

<u>COLUMN</u>	<u>FORMAT</u>	<u>SYMBOL</u>	<u>DEFINITION</u>
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Card 3-1, Descriptive Information for Section 3 Data

NOTE: a) Omit this card if  $IN1 \leq 0$   
b) Supply  $IN1$  physical cards if  $IN1 \geq 1$

1-72	18A4	---	any desired information for description of the input data
73-80	2A4	---	any desired information for card identification

Card 3-2, Energy Levels for Sources and Cross-Sections

NOTE: a) Omit this card if  $IN7 \leq 0$   
b) Supply this card(s) if  $IN7 \geq 1$   
c) Source spectra can be input in any desired group structure and will be regrouped to this set of groups

1-72	8E9.0	ELL(1)	upper energy boundary of the first energy group (Mev)
		ELL(2)	lower energy boundary of the first energy group and upper boundary of the second group
		ELL(NEMAX+1)	Lower energy boundary of the last energy group; also defines the energy cutoff point
72-80	2A4	---	Any desired information for card identification

Card 3-3, Average Neutron Energies After Scatter

NOTE: a) Omit this card if  $IN2 \leq 0$   
b) Supply this card(s) if  $IN2 \geq 1$   
c) This data is required if and only if  $NXSECT=1$  (neutron problem)

1-72	8E9.0	ESB(1)	Average neutron energy for group 1 (Mev)
		ESB(2)	Average neutron energy for group 2
		ESB(NEMAX)	Average neutron energy for the last energy group
73-80	2A4	---	Any desired information for card identification

<u>COLUMN</u>	<u>FORMAT</u>	<u>SYMBOL</u>	<u>DEFINITION</u>
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Card 3-4, Composition Vector for Element

- NOTE: a) Omit Cards 3-4 through 3-8 if  $IN3 \leq 0$   
b) Supply Cards 3-4 through 3-8 as required in sets for each element, i.e., all data for the first element, all data for the second element, etc., through the data for element number NIMAX if  $IN3 \geq 1$   
c) The first element must always be hydrogen

1-72	8E9.0	ATW	atomic weight of the element in atomic mass units
		ZEE	atomic number of the element
		ATD(1)	density of the element in composite material 1, units according to NUNITD
		ATD(2)	density of the element in composite material 2
		ATD(NMMAX)	density of the element in the last composite material
73-80	2A4	---	any desired information for card identification

Card 3-5, Microscopic Total Cross Sections

- NOTE: a) Supply this card immediately after Card 3-4 for each element.

1-72	8E9.0	XST(1)	total microscopic cross section for energy level 1 (photons) or energy group 1 (neutrons), units according to NUNITX
		XST(2)	total microscopic cross section for energy level 2 or energy group 2
		XST(NEMAX)	total microscopic cross section for next-to-last photon energy level or last neutron energy group
		XST(NEMAX+1)	total microscopic photon cross section for the last energy level. Do not input a number for neutrons
73-80	2A4	---	any desired information for card identification

<u>COLUMN</u>	<u>FORMAT</u>	<u>SYMBOL</u>	<u>DEFINITION</u>
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Card 3-6, Neutron Transfer Cross Section Array Limits

- NOTE: a) Omit this card for photon problems  
b) Omit this card for the first element (always hydrogen) of neutron problems  
c) Supply this card after Card 3-5, for all elements except the first of neutron problems

1-72			
1-72	2413	LMAX	LMAX , number of elastic scattering transfer matrices  1 for $P_0$ only  2 for $P_0$ and $P_1$ , etc.  LMAX < 0, indicates total cross sections are transport corrected. (See notes below).
		NDSM	Maximum group-to-group transfer for elastic scattering  1 for in-group only  2 for down 1, etc.
		JMAX	Maximum number of groups for which non-elastic transfer can be initiated. 0, none
		KMX(1)	Maximum non-elastic group-to-group transfer for initial group 1, = 1 for in group only, etc.
		KMX(2)	Maximum non-elastic group-to-group transfer for initial group 2, = 1 for in group only, etc.
		KMX(JMAX)	Maximum non-elastic group-to-group transfer for the last possible initial group, = 1 for in group only, etc.
73-80	2A4	--	Any desired information for card identification

---

NORDER = 1, LMAX = -2, Code transport corrects  $P_0$  elastic transfer using  $P_1$  transfer

NORDER = 1, LMAX = +2, Code transport corrects  $P_0$  elastic transfer and calculates transport cross sections using  $P_1$  transfer

<u>COLUMN</u>	<u>FORMAT</u>	<u>SYMBOL</u>	<u>DEFINITION</u>
		$N\emptyset RDER \geq 2$ , $LMAX = -2$ , Code calculates total cross section using $P_1$ transfer	
		$N\emptyset RDER = 1$ , $LMAX = \pm 1$ , Cross sections used as input	
		$N\emptyset RDER \geq 2$ , $LMAX \geq 2$ , Cross sections used as input	
<u>Card 3-7, Neutron Elastic Transfer Coefficients</u>			
NOTE: a) Supply this card for all elements except the first of neutron problems immediately after Card 3-6.			
1-72	8E9.0	$\sigma_{i \rightarrow k}^1$	(1) $l_{th}$ Legendre moment of the transfer
		XSE(J,K,L)	cross section from group i to k including $2l+1$ coefficient, e.g., GAM-1, GAM-2 printed output
73-80	2A4	--	Any desired information for card identification

(1) Start a card with  $P_0$  in-group transfer for all energy groups

$$\sigma_{i \rightarrow i}^0, i=1, 2, \dots, NEMAX$$

Start a new card with  $P_0$  down 1 transfer for all groups except the last

$$\sigma_{i \rightarrow i+1}^0, i=1, 2, \dots, NEMAX-1$$

Start a new card with  $P_0$  down (NDSM-1) transfer

$$\sigma_{i \rightarrow i + NDSM-1}^0, i=1, 2, \dots, NEMAX - (NDSM-1)$$

Start a new card with  $P_1$  in group transfer

$$\sigma_{i \rightarrow i}^1, i=1, 2, \dots, NEMAX$$

Start a new card with  $P_{|LMAX|} - 1$  down (NDSM-1) transfer

$$\sigma_{i \rightarrow i + NDSM-1}^{|LMAX|}, i = 1, 2, \dots, NEMAX - (NDSM-1)$$

#### Card 3-8, Neutron Non-Elastic Transfer Coefficients

NOTE: a) Supply this card for all elements -- except the first -- of neutron problems immediately after Card 3-7

b) Omit if JMAX = 0

1-72	8E9.0	$\sigma_{i \rightarrow i + k - 1}^{ne}$	(1) Non-elastic transfer coefficient from
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<u>COLUMN</u>	<u>FORMAT</u>	<u>SYMBOL</u>	<u>DEFINITION</u>
		XSI(K,J)	group i to group i + k - 1 $= \sigma_{i \rightarrow i + K - 1}^{\text{inelastic}} + 2 \sigma_{i \rightarrow i + k - 1}^{\text{n} - 2\text{n}} + \dots$
73-80	2A4	--	Any desired information for card identification
(1) Start the first card with non-elastic transfer from group 1			
		$\sigma_{1 \rightarrow 1 + K - 1}^{\text{ne}}$	K = 1, 2, ..., KMX(1)
Start a new card with non-elastic transfer from group 2			
		$\sigma_{2 \rightarrow 2 + K - 1}^{\text{ne}}$	K = 1, 2, ..., KMX(2)
Start a new card with non-elastic transfer from group JMAX			
		$\sigma_{\text{JMAX} \rightarrow \text{JMAX} + K - 1}^{\text{ne}}$	K = 1, 2, ..., KMX (JMAX)
<u>Card 3-9, Material-In-Region Indices</u>			
NOTE: a) Omit this card if $\text{IN}4 \leq 0$			
b) Supply this card if $\text{IN}4 \geq 1$ with material indices for $\text{IN}4$ regions			
c) These indices can also be input on Card 2-3			
1-72	2413	I	First region index
		MTL(I)	>0, index of material in this region
			=0, region contains hydrogen only
			<0, region is void
			K=1
		I	Second region index
		MTL(I)	Material index for region
			K=2
		I	Last region index
		MTL(I)	Material index for region
			K=IN4
73-80	2A4	--	Any desired information for card identification

<u>COLUMN</u>	<u>FORMAT</u>	<u>SYMBOL</u>	<u>DEFINITION</u>	
<u>Card 3-10 Hydrogen Density in Region</u>				
NOTE: a) Omit this card if $IN5 < 0$				
b) Supply this card if $IN5 \geq 1$ with densities for $IN5$ regions				
c) These densities can also be entered on Card 2-3				
1-72	6(13,E9.0)	I	First region index	} K=1
		RHØ(I)	Hydrogen density in region I units according to NUNITD	
		I	Second region index	} K=2
		RHØ(I)	Hydrogen density in region I	
		I	Last region index	} K=IN5
		RHØ(I)	Hydrogen density in region I	
73-80	2A4	--	Any desired information for card identification	

## SECTION 4 DATA: DETECTOR AND FLUX CONVERSIONS

### Card 4-0, Input Controls for Section 4 Data

NOTE: a) This card is always required

<u>COLUMN</u>	<u>FORMAT</u>	<u>SYMBOL</u>	<u>DEFINITION</u>
1-3	I3	IN1	Input control for Card 4-1 (descriptive cards) Omit Card 4-1 if $IN1 \leq 0$ Supply IN1 physical cards if $IN1 \geq 1$
4-6	I3	IN2	Input control for Card 4-2 (flux groups) Omit Card 4-2 if $IN2 \leq 0$ Supply Card 4-2 if $IN2 \geq 1$
7-9	I3	IN3	Input control for Card 4-3 (response functions) Omit Card 4-3 if $IN3 \leq 0$ Supply IN3 response functions if $IN3 \geq 1$
10-12	I3	IN4	Input control for Card 4-4 (detectors) Omit Card 4-4 if $IN4 \leq 0$ Supply IN4 detectors if $IN4 \geq 1$
13-15	I3	IN5	Input control for Card 4-5 ( $\Delta$ total flux sources) Omit Card 4-5 if $IN5 \leq 0$ Supply Card 4-5 if $IN5 \geq 1$
16-18	I3	IN6	Input control for Card 4-6 (scattered flux regions) Omit Card 4-6 if $IN6 \leq 0$ Supply Card 4-6 if $IN6 \geq 1$
19-72	18I3	--	These columns are not used and should be left blank
73-80	2A4	--	Any desired information for card identification

### Card 4-1, Descriptive Information for Section 5 Data

NOTE: a) Omit this card if  $IN1 \leq 0$   
b) Supply IN1 physical cards if  $IN1 \geq 1$

1-72	18A4	--	Any desired information for describing the input data
73-80	2A4	--	Any desired information for card identification

<u>COLUMN</u>	<u>FORMAT</u>	<u>SYMBOL</u>	<u>DEFINITION</u>
<u>Card 4-2, Flux Groups</u>			
NOTE: a) Omit this card if $IN2 \leq 0$ b) Supply this card if $IN2 \geq 1$ c) This card is required if the number of flux groups (NGMAX) is less than the number of groups (NEMAX) used to run the problem			
1-72	24I3	NTG(1)	index of flux group corresponding to first source and cross section group, = 1
		NTG(2)	index of flux group corresponding to the second source and cross section group
		NTG(NEMAX)	index of flux group corresponding to the last source and cross section group, = NGMAX
73-80	2A4	--	any desired information for card identification

Card 4-3, Response Functions

NOTE: a) Omit this card if  $IN3 \leq 0$   
b) Supply this card for  $IN3$  response functions if  $IN3 \geq 1$

1-3	I3	I	index of the response function
4-6	I3	NTP	response function type, 0, number flux response input by flux group boundary with units (response/particle $\text{cm}^{-2} \text{sec}^{-1}$ )  1, energy flux response input by flux group boundary with units (response/Mev $\text{cm}^{-2} \text{sec}^{-1}$ )  <0, energy deposition response function for region 1' = -NTP with units (Mev $\text{cm}^{-3} \text{sec}^{-1}$ /particle $\text{cm}^{-2} \text{sec}^{-1}$ ). NTP <0 requires input of microscopic cross sections in Section 4 data for this problem. (Requires no other input after Column 27 of this card. The response function will appear on the print-out immediately below the data on this card.)
7-18	3A4	--	any desired description of the response function used in labeling the output
19-27	E9.0	FST	response function scaling factor, this multiplicative factor can be used to convert the response units to more useful units. Do not use FST = 0.0.

<u>COLUMN</u>	<u>FORMAT</u>	<u>SYMBOL</u>	<u>DEFINITION</u>
28-36	E9.0	RSP(1,1) ⋮	response function for upper boundary of the first flux group. Leave blank if NTP < 0
63-72	E9.0	RSP(5,1)	response function for the upper boundary of the 5th flux group (lower boundary of the 4th flux group). Continue on Card 5-3' if more than 4 flux groups and NTP ≥ 0. Leave blank if NTP < 0
73-80	2A4	--	any desired information for card identification

#### Card 4-3', Response Function Continuation

NOTE: Supply this card immediately behind Card 5-3 if there are more than 4 flux groups and if NTP ≥ 0.

1-72	8E9.0	RSP(6,1)	response function for the lower boundary of the 5th flux group (upper boundary of the 6th group).
		RSP(NGMAX+1,1)	response function for the lower boundary of the last flux group
73-80	2A4	--	any desired information for card identification

#### Card 4-4, Detectors

NOTE: a) omit this card if IN4 ≤ 0  
b) supply IN4 physical cards if IN4 ≥ 1

1-3	I3	I	index of the detector being described
4-6	I3	IDR(1)	0, for point detector >0, region index for a surface or volume detector
7-9	I3	IDS(1)	0 for a point detector 0 for a volume detector >0, surface index for a surface detector (the detector is that part of surface IDS(1) which bounds region IDR(1) )
10-18	E9.0	VØL(1)	not used for point detector; region volume (cm <sup>3</sup> ) for volume detector; detector area (cm <sup>2</sup> ) for surface detector (1.0 yields surface or volume integrated fluxes)

<u>COLUMN</u>	<u>FORMAT</u>	<u>SYMBOL</u>	<u>DEFINITION</u>
19-27	E9.0	CDT(1,1)	relative direction cosine with respect to the x - axis of the unit direction vector used in obtaining Legendre moments of the angular flux (not used for surface detectors, angular moments are obtained with respect to the surface normal).
28-36	E9.0	CDT(2,1)	relative direction cosine with respect to the y - axis
37-45	E9.0	CDT(3,1)	relative direction cosine with respect to the z - axis, the 3 direction cosines are normalized by the program
46-54	E9.0	XDT(1,1)	x coordinate if a point detector (cm)
55-63	E9.0	XDT(2,1)	y coordinate if a point detector (cm)
64-72	E9.0	XDT(3,1)	z coordinate if a point detector (cm)
73-80	2A4	--	any desired information for card identification

#### Card 4-5, Flux Contribution Sources

NOTE: a) omit this card if  $IN5 \leq 0$   
b) supply this card if  $IN5 \geq 1$

1-72	24I3	ISV(1)	index of first source for which the individual scalar flux contribution is required
		ISV(NVMØD)	index of the last source for which the individual scalar flux contribution is required
73-80	2A4	--	any desired information for card identification

#### Card 4-6, Scattered Flux by Scattering Region

NOTE: a) omit this card if  $IN6 \leq 0$   
b) supply this card if  $IN6 \geq 1$

1-72	24I3	ISR(1)	index of the first non-void region from which the individual scattered scalar flux contribution is required
		ISR(NSRMAX)	index of the last non-void region from which the scattered flux contribution is required
73-80	2A4	--	any desired information for card identification

<u>COLUMN</u>	<u>FORMAT</u>	<u>SYMBOL</u>	<u>DEFINITION</u>
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# SECTION 5 DATA; RANDOM SAMPLING PARAMETERS

## Card 5-0, Input Controls for Section 5 Data

NOTE: This card is always required

1-3	I3	IN1	input control for Card 5-1 (descriptive cards) omit Card 5-1 if $IN1 \leq 0$ supply IN1 physical cards if $IN1 \geq 1$
4-6	I3	IN2	input control for Card 5-2 (spherical source and detector) omit Card 5-2 if $IN2 \leq 0$ supply Card 5-2 if $IN2 \geq 1$
7-9	I3	IN3	input control for Card 5-3 (source importance) omit Card 5-3 if $IN2 \leq 0$ supply Card 5-3 if $IN3 \geq 1$
10-12	I3	IN4	input control for Card 5-4 (source variable importance) omit Card 5-4 if $IN4 \leq 0$ supply Card 5-4 if $IN4 \geq 1$
13-15	I3	IN5	input control for Card 5-5 (group importance) omit Card 5-5 if $IN5 \leq 0$ supply Card 5-5 if $IN5 \geq 1$
16-18	I3	IN6	input control for Card 5-6 (linear buildup) omit Card 5-6 if $IN6 \leq 0$ supply Card 5-6 if $IN6 \geq 1$
19-21	I3	IN7	input control for Card 5-7 (heavy element scatter) omit Card 5-7 if $IN7 \leq 0$ supply Card 5-7 if $IN7 \geq 1$
22-24	I3	IN8	input control for Card 5-8 (hydrogen scatter) omit Card 5-8 if $IN8 \leq 0$ supply Card 5-7 if $IN7 \geq 1$
25-27	I3	IN9	input control for Card 5-9 (scaling factors) omit Card 5-9 if $IN9 \leq 0$ supply Card 5-9 if $IN9 \geq 1$
28-72	15I3	--	these columns are not used and should be left blank
73-80	2A4	--	any desired information for card identification

<u>COLUMN</u>	<u>FORMAT</u>	<u>SYMBOL</u>	<u>DEFINITION</u>
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Card 5-1, Descriptive Information for Section 5 Data

NOTE: a) omit this card if  $IN1 \leq 0$   
b) supply  $IN1$  physical cards if  $IN1 \geq 1$

1-72	18A4	--	any desired information for describing Section 6 data.
73-80	2A4	--	any desired information for card identification

Card 5-2, Spherical Pseudo-Source and Detector

NOTE: a) omit this card if  $IN2 \leq 0$   
b) supply this card if  $IN2 \geq 1$

1-9	E9.0	RADIUS	radius of a pseudo spherical source which encloses all the fixed sources (cm)
10-18	E9.0	XCT(1)	x - coordinate of the center of the sphere (cm)
19-27	E9.0	XCT(2)	y - coordinate of the center of the sphere (cm)
28-36	E9.0	XCT(3)	z - coordinate of the center of the sphere (cm)
37-45	E9.0	DELTA	radius of a pseudo spherical detector which covers the area in space where fluxes are being calculated; the center of this sphere is the "preferred point" for surface and volume flux calculations (not used if $NPOINT = 1$ )
46-54	E9.0	BDC(1)	x - coordinate of the center of the detector sphere (cm)
55-63	E9.0	BDC(2)	y - coordinate of the center of the detector sphere (cm)
64-72	E9.0	BDC(3)	z - coordinate of the center of the detector sphere (cm)
73-80	2A4	--	any desired information for card identification

<u>COLUMN</u>	<u>FORMAT</u>	<u>SYMBOL</u>	<u>DEFINITION</u>
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Card 5-3, Relative Source Importances

- NOTE: a) omit this card if  $IN3 \leq 0$   
b) supply this card if  $IN3 \geq 1$   
c) the data on this card is required if, and only if,  $MODEL P = 0$  and more than one source is present

1-72	8E9.0	RSI(1)	relative importance of fixed source number 1, (use intuitive knowledge or, better yet, a point kernel calculation of fractional contributions from each source).
		RSI(NVMAX)	relative importance of the last fixed source (these importances are normalized in the program)
73-80	2A4	--	any desired information for card identification

Card 5-4, Source Variable Sampling (preferred values)

- NOTE: a) omit this card if  $IN4 \leq 0$   
b) supply this card and Card 5-4' for all sources if  $IN4 \geq 1$   
c) The first three pieces of data on this card are required if  $MODEL P = 0$ .  
d) The last two pieces of data are required if  $MODEL Q = 0$

1-9	E9.0	VMD(1,1)	preferred value of the first source variable of the 1th source, must be in the range of the variable including the minimum and maximum values
46-72	3E9.0	--	these columns are not used and should be left blank
73-80	2A4	--	any desired information for card identification

Card 5-4', Source Variable Sampling (relative importance)

- NOTE: a) omit this card if  $IN4 \leq 0$   
b) supply this card immediately behind Card 5-4 for the same source if  $IN4 \geq 1$ , i.e.,

Card 5-4 } Source 1  
Card 5-4' }

Card 5-4 } Last Source  
Card 5-4' }

- c) all numbers on this card must be greater than 0.0.

<u>COLUMN</u>	<u>FORMAT</u>	<u>SYMBOL</u>	<u>DEFINITION</u>
1-9	E9.0	ALP(1,1)	relative importance of the preferred value of the first source variable for the 1th source, expressed as a ratio to the importance of the value of the variable furthest away (either the minimum or maximum value of the variable)  >1.0, the preferred point is more important  $0.0 < \text{ALP}(1,1) < 1.0$ the preferred point is less important  = 1.0, all points are equally important (this number must be >0.0 since its logarithm is computed)
37-45	E9.0	ALP(5,1)	relative importance of the preferred value of the fifth source variable of the 1th source.
46-72	3E9.0	--	these columns are not used and should be left blank
73-80	2A4	--	any desired information for card identification

#### Card 5-5, Group Importance

NOTE: a) omit this card if  $\text{IN5} \leq 0$   
b) supply this card if  $\text{IN5} \geq 1$

1-72	8E9.0	GIM(1)	relative importance of particles in the first source and cross section group; e.g., an average flux-to-dose conversion factor for the first group
		GIM(NEMAX)	relative importance of particles in the last source and cross section group; e.g., an average flux-to-dose conversion factor for the last group
73-80	2A4	--	any desired information for card identification

#### Card 5-6, Linear Building Coefficients

NOTE: a) omit this card if  $\text{IN6} \leq 0$   
b) supply this card if  $\text{IN6} \geq 1$

<u>COLUMN</u>	<u>FORMAT</u>	<u>SYMBOL</u>	<u>DEFINITION</u>
1-72	8E9.0	AIM(1)	linear buildup coefficient for group 1 used to estimate the importance of future collisions, this number, when multiplied by the mean free paths to a detector, is used to approximate the future scattered contributions
		AIM(NEMAX)	linear buildup coefficient for the last source and cross section group
73-80	2A4	--	any desired information for card identification

#### Card 5-7, Heavy Element Scattering Importance

- NOTE: a) omit this card if  $IN7 < 0$   
b) supply this card if  $IN7 \geq 0$   
c) all numbers on this card must be greater than 0.0.

1-72	8E9.0	ALM(1)	ratio of forward-to-backward scattering importance for heavy elements for the first energy group (see note below.)
		ALM(NEMAX)	similar ratio for the last energy group
73-80	2A4	--	any desired information for card identification

---

NOTE: For neutrons, a ratio of 10.0 for each group has worked well; for photons, the ratio

$$\frac{d\Sigma}{d\Omega} (0^\circ \text{ scatter}) \times \text{energy after scatter } (0^\circ)$$

$$\frac{d\Sigma}{d\Omega} (180^\circ \text{ scatter}) \times \text{energy after scatter } (180^\circ)$$

using the Klein-Nishina formula for an average group energy has yielded good results

#### Card 5-8, Hydrogen Scattering Importance

- NOTE: a) omit this card if  $IN8 < 0$   
b) supply this card if  $IN8 \geq 1$   
c) all numbers on this card must be greater than 0.0

1-72	8E9.0	ALH(1)	ratio of forward-to-backward scattering importance for hydrogen for the first energy group (see notes below)
		ALH(NEMAX)	ratio of forward-to-backward scattering importance for hydrogen for the last energy group

<u>COLUMN</u>	<u>FORMAT</u>	<u>SYMBOL</u>	<u>DEFINITION</u>
73-80	2A4	--	any desired information for card identification

NOTES: For neutrons, there is no back scattering from hydrogen; large ratios, e.g.,  $10^3$  for each group have worked well. For photons, numbers identical to those on Card 5-7 have been used

These numbers are applied only to the hydrogen density specified for the region, they are not applied to the hydrogen part, if any, of material compositions. Therefore, it is essential in neutron problems, that the hydrogen densities be specified by region to properly approximate the angular dependence of neutron scattering from hydrogen

#### Card 5-9, Sampling Parameter Scaling Factors

NOTE: a) omit this card if  $IN9 \leq 0$   
b) supply this card if  $IN9 \geq 1$

1-9	E9.0	ATA	spherical pseudo source sampling, polar angle importance adjustment  1.0, all angles equally important, >1.0, shifts importance towards small angles, <1.0, shifts importance towards large angles, Numbers in the range $1.0 \leq ATA \leq 10.0$ work fine (This number must be greater than 0.0)
10-18	E9.0	ATB	spherical pseudo source sampling, azimuthal angle important adjustment, 1.0, all angles equally important, >1.0, shifts importance towards $0^\circ$ <1.0, shifts importance away from $0^\circ$ This angle is measured in a rotated coordinate system and a little difficult to relate to the true coordinate system. The usual procedure is to use $ATB = 1.0$ (this number must be greater than 0.0)
19-27	E9.0	ATC	spherical pseudo-source sampling, spatial importance adjustment 1.0, uses built-in estimate of spatial importance >1.0, shifts importance to lower source energies (source points closer to the detector) <1.0, shifts importance to higher source energies (source points further away) General use of numbers $0.7 < ATC < 1.3$ yield results

<u>COLUMN</u>	<u>FORMAT</u>	<u>SYMBOL</u>	<u>DEFINITION</u>
			(the program can be <u>tricked</u> for leakage-type surface and volume detector calculations by putting the preferred detector in the center of the source and using ATC $\sim -1.0$ )
28-36	E9.0	ATD	flux contribution importance used in cutoff considerations; if all contributions to all detector groups on 2 successive inner iterations of a given outer iteration are less than ATD times the flux already obtained in this outer iteration, then the inner iterations are terminated
37-45	E9.0	AT	scaling factor for the spatial importance on the first leg of the scattering triangle 1.0 uses built-in parameters <1.0, shifts importance to higher energies >1.0, shifts importance to lower energies general use of numbers $0.6 < AT < 1.2$ yields good results (must be greater than 0.0)
46-54	E9.0	BT	scaling factor for the spatial importance on the second leg of the scattering triangle; should approximate higher order scattering effects, so it is generally less than AT If $M\bar{O}DELU = 0$ , it must be less than AT in absolute magnitude, i.e., $ BT  \leq AT$ numbers on the order of $0.4 < BT < 0.9$ yield good results (if the <u>trick</u> mentioned in discussing ATC is used, it should also be used here; i.e., $-0.9 < BT < -0.4$ .) this number cannot = 0.0
55-63	E9.0	AS	scaling factor for preferred direction (towards detector) importance 1.0 uses built-in parameter >1.0 forces even more <1.0 forces less 0.0 yields no effect (<0.0 forces away and should be used when ATC and BT are <0.0) use of 1.0 yields good results for point detectors
64-72	E9.0	BS	scaling factor for scattered direction importance 1.0, uses group averaged parameter >1.0 forces even more <1.0, forces less 0.0, no effect from scattered direction use of 1.0 yields good results
73-80	2A4	--	any desired information for card identification

## SECTION 6 DATA; SOURCE DISTRIBUTIONS\*

### Card 6-0, Input Controls for Section 3 Data

NOTE: a) This card is always required

<u>COLUMN</u>	<u>FORMAT</u>	<u>SYMBOL</u>	<u>DEFINITION</u>
1-3	I3	IN1	input control for Card 6-1 (descriptive cards) omit Card 6-1 if $IN1 \leq 0$ supply IN1 physical card if $IN1 \geq 1$
4-6	I3	IN2	input control for energy levels do not calculate $\Delta$ energy levels if $IN2 \leq 0$ calculate $\Delta$ energy levels if $IN2 \geq 1$
7-9	I3	IN3	input control for fixed sources, omit Cards 6-2 through 6-4 if $IN3 \leq 0$ . Supply Cards 6-2, 6-3 and 6-4 as required for IN3 fixed sources if $IN3 \geq 1$
10-12	I3	IN4	input control for Card 6-5 (source-in- region) omit Card 6-5 if $IN4 \leq 0$ supply source in region indices on Card 6-5 for IN4 regions if $IN4 \geq 1$
13-15	I3	IN5	input control for problem termination terminate problem for $IN5 \geq 1$ Do not terminate problem for $IN5 \leq 0$
16-18	I3	IN6	input control for Card 6-6 (time cards) omit Card 6-6 if $IN6 \leq 0$ supply IN6 quantities for $IN6 \geq 1$
19-21	I3	IN7	input control for time result cumulations initialize sum for $IN7 \geq 1$ Do not initialize sum for $IN7 \leq 0$
22-24	I3	IN8	input control for source variable sampling (preferred values) initialize source variable preferred values for $IN8 \geq 1$ do not initialize source variable preferred values for $IN8 \leq 0$
25-72	16I3	---	these columns are not used and should be left blank
73-80	2A4	---	any desired information for card identification

\* Note: This entire section of input data is prepared by NAP for the gamma ray shielding calculation by the INAP System.

<u>COLUMN</u>	<u>FORMAT</u>	<u>SYMBOL</u>	<u>DEFINITION</u>
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Card 6-1, Description of Section 3 Data

NOTE: a) omit this card if  $IN1 \leq 0$   
b) supply  $IN1$  physical cards if  $IN1 \geq 1$

1-72	18A4	---	any desired information for describing the input data
73-80	2A4	---	any desired information for card description

Card 6-2, Fixed Source Constants and Input Options

NOTE: a) omit this card if  $IN3 \leq 0$   
b) supply this card, and Cards 6-3 and 6-4 as required, for  $IN3$  sources if  $IN3 \geq 1$

1-3	13	I	index of source being described
4-6	13	NSG(1)	source geometry type 0, rectangular 1, cylindrical 2, spherical
7-9	13	NPC(1,1)	first spatial variable distribution option (see notes below)
10-12	13	NPC(2,1)	second spatial variable distribution option (see notes below)
13-15	13	NPC(3,1)	third spatial variable distribution option (see notes below)
16-18	13	NPC(4,1)	azimuthal part of angular distribution option (fourth source variable) (see notes below)
19-21	13	NPC(5,1)	polar part of the angular distribution, option (fifth source variable) (see notes below)

<u>COLUMN</u>	<u>FORMAT</u>	<u>SYMBOL</u>	<u>DEFINITION</u>
---------------	---------------	---------------	-------------------

NOTES: The source variables are shown in Figure 10 and are ordered as:

	<u>Rectangular</u>	<u>Cylindrical</u>	<u>Spherical</u>
J = 1	x (cm)	r (cm)	$\rho$ (cm)
J = 2	y (cm)	$\theta$ (radians)	$\theta$ (radians)
J = 3	z (cm)	z (cm)	$\mu$
J = 4	$\theta'$ (radians)	$\theta'$ (radians)	$\theta'$ (radians)
J = 5	$\mu'$	$\mu'$	$\mu'$

Azimuthal angles are in the range  $-\pi \leq \theta, \theta' \leq \pi$

Cosines of polar angles are in the range  $-1 \leq \mu, \mu' \leq 1$

If NPC (J,1) >0, this is the number of tabulation points required to describe the J<sup>th</sup> distribution using Card 6-3. If NPC(J,1) <0, the distribution for variable J of source 1' = -NPC(J,1) is used and Card 6-3 is not required

22-24	13	MAX	>0, number of energy points or energy groups required to describe the source spectrum <0, use the source spectrum for source number 1'=-MAX
25-27	13	NORM	spectrum normalization option (the total source strength is carried in the spectrum) 0, normalize to total source in particles/sec; 1, normalize to total source in Mev/sec; 2, multiply spectrum by constant (if used with MAX<0, remember that the spectrum for source 1' = - MAX has been normalized to the total source strength)
28-30	13	ISP	input spectrum units option if MAX>0 0, differential number spectrum at energy points; 1, differential energy spectrum at energy points; 2, groupwise number spectrum (particles in group); 3, groupwise energy spectrum (energy in group)
31-33	13	IAL	Spectrum format option if MAX >0 0, alternating values of energy points and spectrum 1, spectrum input only using energy points previously input for this case 2, energy point input followed by spectrum input on separate card

<u>COLUMN</u>	<u>FORMAT</u>	<u>SYMBOL</u>	<u>DEFINITION</u>
34-36	I3	---	these columns are not used and should be left blank
37-45	E9.0	TØT	source normalization constant, particles/sec if NØRM = 0, Mev/sec if NØRM = 1, multiplying constant if NØRM = 2
46-54	E9.0	XTR(1,I)	x component of the translation of the source coordinate system origin from the geometry coordinate system origin (cm)
55-63	E9.0	XTR(2,I)	y component of the source translation (cm)
64-72	E9.0	XTR(3,I)	z component of the source translation (cm)
73-80	2A4	---	any desired information for card identification

#### Card 6-3, Source Variable Distributions

- NOTE: a) supply these cards immediately behind Card 6-2 for the source to which they apply. Input for each variable in the order J = 1,2,3,4,5, starting a new physical card for each variable  
b) omit for any variable for which NPC(J,I) < 0  
c) this distribution is normalized and interpolated linearly  
d) histogram data can be used (points can coincide)

1-72	8E9.0	VEE(1,J,I)	minimum value of the <u>J</u> th variable; if NPC(J,I) = 1, this is the only value of the variable
		VAL(1,J,I)	relative value of the distribution function for the <u>J</u> th variable at its minimum value (not used if the variable is discrete, NPC(J,I) = 1)
		VEE(K,J,I)	Kth value of the <u>J</u> th variable
		VAL(K,J,I)	relative value of the distribution function corresponding to VEE(K,J,I)
		VEE(L,J,I)	maximum value of the <u>J</u> th variable where L=NPC(J,I), the last tabulation point
		VAL(L,J,I)	relative value of the distribution function corresponding to VEE(L,J,I)
73-80	2A4	--	any desired information for card identification

<u>COLUMN</u>	<u>FORMAT</u>	<u>SYMBOL</u>	<u>DEFINITION</u>
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NOTE: To avoid numerical difficulties, it is sometimes necessary to decrement the minimum value and increment the maximum value of these variables. In particular, for a uniform azimuthal distribution angular limits use 3.1416 ( $>\pi$ ) for  $\pi$  rather than 3.14159 ( $<\pi$ ) since the computer uses more significant figures than can be input

#### Card 6-4, Source Spectrum

NOTE: a) supply this card(s) if and only if MAX>0. It should be placed immediately after the source variable distributions, if any.

1-72	8E9.0	---	see notes below
73-80	2A4	---	any desired information for card identification

NOTES: A. If  $ISP \leq 1$ , the differential spectrum is tabulated at discrete energy points where

$E(1)$  is the maximum spectral energy (Mev)

$E(MAX)$  is the minimum spectral energy

$EN(K)$  is the differential spectrum corresponding to the  $K$ th energy point  $E(K)$ . The units of  $EN(K)$  are particles/Mev if  $ISP = 0$  or Mev/Mev if  $ISP = 1$

A.1 If  $IAL = 0$ , the input on Card 6-4 consists of alternating values of energy and spectrum

$E(1), EN(1), E(2), EN(2), \dots, E(MAX), EN(MAX)$

A.2 If  $IAL = 1$ , the energy points are already defined by prior input for this case (they will not be available from a previous case). The input consists of the relative spectrum at these points

$EN(1), EN(2), \dots, EN(MAX)$

A.3 If  $IAL = 2$ , the energy points are defined first

$E(1), E(2), \dots, E(MAX)$

and then followed by another card with the corresponding spectrum

$EN(1), EN(2), \dots, EN(MAX)$

B. If  $ISP \geq 2$ , a groupwise integrated spectrum is tabulated by group where  $EBG(1)$  is the upper energy boundary of group 1

<u>COLUMN</u>	<u>FORMAT</u>	<u>SYMBOL</u>	<u>DEFINITION</u>
NOTES(Continued)			EBG(MAX+1) is the lower energy boundary of the last spectrum group ENG(K) is the integral spectrum for the K <sup>th</sup> group with units of particles in group K if ISP=2, or Mev. in group K if ISP = 3
B.1			If IAL = 0, the input on Card 6-4 consists of alternating values of energy group boundaries and group spectrum EBG(1), ENG(1), EBG(2), ENG(2), ..., EBG(MAX), ENG(MAX), EBG(MAX+1)
B.2			If IAL = 1, the energy group boundaries are already defined and the groupwise spectrum is supplied on Card 6-4 ENG(1), ENG(2), ..., ENG(MAX)
B.3			If IAL = 2, the energy group boundaries are defined first EBG(1), EBG(2), ..., EBG(MAX+1) and then followed by another card with groupwise spectrum ENG(1), ENG(2), ..., ENG(MAX)

#### Card 6-5, Source in Region Indices

- NOTE: a) omit this card if  $IN4 \leq 0$   
b) supply this card(s) if  $IN4 \geq 1$  with source indices for  $IN4$  regions  
c) this data is required if and only if MODEL P=1  
d) this data can also be input on Card 2-3

1-72	2413	I	first geometric region index	K=1
		ISV(I)	index of source superimposed over Region I (source which completely covers the region), 0 denotes none	
		I	second geometric region index	K=2
		ISV(I)	index of source superimposed over Region I (source which completely covers the region)	
		I	last geometric region index	K=IN4
		ISV(I)	index of source superimposed over region I (source which completely covers the region)	
73-80	2A4	---	any desired information for card identification	

<u>COLUMN</u>	<u>FORMAT</u>	<u>SYMBOL</u>	<u>DEFINITION</u>
<u>Card 6-6, Time Cards</u>			
NOTE: a) omit this card if $IN6 < 0$ b) supply a maximum of $IN6$ values on this card if $IN6 \geq 1$ c) this card is required only for the INAP gamma ray shielding calculations			
1-72	8E9.0	TIME 1	initial time of dose calculation interval or time of dose rate calculation
		TIME 2	End time of dose calculation (not used in dose rate calculations)
73-80	2A4	---	any desired information for card identification

Section 6 cards are repeated as necessary to describe the various source region dependencies.

### 3.2.3 Output Description

In addition to the FASTER output described in Reference 10, the INAP version of FASTER generates output specifically for the INAP system. In the neutron transport mode, this output consists of punched cards and some additional print out. The punched cards are those quantities used by the NAP code in describing the volume averaged neutron flux within the activated regions (see Figure 3.6-1). The printed output is merely a summary of these cards. This printing occurs throughout the normal FASTER output and is easily identified as differing from the normal FASTER output by its characteristic format.

For the gamma part of the problem, the output consists of printed output added to the normal FASTER printed output. For the dose rate calculation it is simply an additional line of output heading indicating the time at which the dose rate is calculated. For the dose calculation, there is the additional line of output heading to give the interval of time over which the dose calculation is computed and an entirely new section of output appropriately labeled to give the cumulative dose to the time indicated for each detector.

### 3.3 Activation and Decay Chain Module

It is the purpose of this code module to compute the activation gamma ray source strength in each neutron volume detector specified in FASTER/INAP. The neutron flux is used along with the specified isotopic compositions of the material zones to compute the production rates of the radioactive isotopes resulting from various neutron induced reactions. With this information and a specified, time varying "power level" describing the time dependence of the neutron sources the decay chain calculations are performed and the activation gamma ray source strengths are determined at specific times or integrated between specified times. This information is then punched out in the proper order and format to be input as the source strength for FASTER gamma ray shielding calculations. The NAP<sup>(8)</sup> program has been modified to perform this function in the Accurate System.

#### 3.3.1 Operating Instructions

For a detailed description of the INAP program the user should refer to Reference 8 which provides a complete users manual. Therefore, the information provided herein is intended only to document the changes which were made to integrate NAP into the INAP Accurate System. Since several changes were made in the required input, Section 3.3.2 provides a complete description of the NAP/INAP input. However, since many of the variable definitions are unchanged from those of the INAP Engineering System, they are not repeated in Section 3.3.2. The user should refer to Section 2.3.2 of this report for the definitions of these variables. Section 3.3.3 provides a brief description of the modifications to the NAP output format. The following paragraphs will provide operating instructions and a description of the modifications which were incorporated into NAP.

The principal modification was to deactivate the neutron transport calculation performed by NAP since this is now performed by FASTER. The average neutron flux for each region is prepared by FASTER for input to NAP in the FLXIN array. In addition, the neutron energy group structure and the volumes of the detector regions are provided by FASTER for input to NAP. A flag, IQXT, has been added to the INAP version to suppress a

great deal of the nonessential output and several variables and arrays which were required to perform the neutron transport calculation, have been eliminated from the input.

Since NAP automatically assumes the energy of the first neutron group to be 21.17 MeV, reaction cross sections may be averaged over a much wider range than desired and reactions with threshold energies greater than the greatest neutron energy may be introduced. This has been eliminated in the INAP version by introducing a "dummy" energy group whose energy range extends from the upper energy of the first neutron group of the FASTER calculation up to 21.17 MeV. The flux in this group is set to zero automatically by NAP. No inconsistency will result if the upper energy of the first FASTER group is 21.17 MeV.

It was also found to be more convenient to input several variables describing source parameters required by FASTER for the gamma ray shielding calculation into NAP to eliminate the need to insert additional data cards into the FASTER input deck prepared by NAP. These variables are defined in Section 3.4.2 with the remainder of the FASTER input description.

Correct operation of the NAP program requires placement of the NAP Cross Section Library tape on FØRTRAN tape unit 8 and the NAP Gamma Radiation Library tape on FØRTRAN tape unit 10. FØRTRAN logical file 1 is used to store any cross section data submitted by the program user. FØRTRAN logical file 2 is used for temporary storage during program operation. FØRTRAN logical file 20 is used to store dose and dose rate calculational quantities to be output for use in the FASTER part of the INAP Accurate System. The nominal FØRTRAN logical files 5, 6, and 7 are used for input, output, and punch.

### 3.3.2 Input Description

This section indicates the input variables and specifies the input format for each input card necessary in using the accurate INAP version of the NAP program. Except for the first input card, which is the problem title and may contain any of the alphabetic and numerical characters, all input data to the NAP program are integer numerical characters, all input data to the NAP program are integer numbers or floating point numbers. Those pieces of data which are output by the FASTER code in the INAP system are noted. Since nearly all the NAP variables have been described and defined in Section 2.4.2 of this report, to repeat them here would be redundant. Therefore, only the input variables which differ from those defined in the Engineering System will be defined in this section.

Card Type 1, format 12A6; Problem Title.

Card Type 2, format 10I55; NØREG, NØBG. (Output by FASTER in INAP system).

Card Type 3, format 6E12.5; ELIM(I). (Output by FASTER in INAP system).

Card Type 4, format E12.5; VØL(J). (Output by FASTER in INAP system). VØL(J) is the volume of region J.

Card Type 5, format 6E12.5; FLXIN(I). (Output by FASTER in INAP system).

Cards 4 and 5 are repeated for all regions, J; J = 1, 2, 3, ..., NØREG.

Card Type 6, format 15, 1WT.

Card Type 7, format 10I5; IQXT.

Card Type 8, format 10I5; NØGG.

Card Type 9, format 6E12.5; EGG(I).

Card Type 10, format E12.5; TFAC, NØNV.

Card Type 11, format 3 (2I6, E12.5); NZ(I), NA(I), VFAC(I).

Card Type 12, format 2I6; NØPER.

Card Type 13, format 6E12.5; PØW(I).

Card Type 14, format 6E12.5; TI(I).

Card Type 15, format 12I6, NINT(I).

Card Type 16, format 15; NTIME.

Card Type 17, format 6E12.5; TIME(I).

Card Type 18, format 16; NX.

Card Type 19, format 10E8.1; X(M).

Card Type 20, format 1015; ~~MODEL~~P, IN8. (Input to be passed on to FASTER for INAP system).

These quantities are described in Section 3.2.2 (FASTER input) as are the quantities on the following 4 card types. The options associated with these cards are the same as for FASTER and only the format of the cards has changed from that of FASTER.

Card Type 21, format 1015, NSG(IR), NPC(J,IR), J = 1, ..., 5 (IR is the region index).

Card Type 22, format 6E12.5, XTR(J,IR), J = 1,2,3.

Card Type 23, format 6E12.5, VEE(K,J), VAL(K,J), K = 1,..., NPC(J,IR), J = 1,...,5.

Card Type 24, format 1015; ISV(IR), required if MODEL~~P~~>0.

Card Type 25, format 112, 4E12.5; ISØR, TEMP, RD.  
(See Section 2.3.2, card type 23.)

Card Type 25, format 3(213, 16, E12.5); IZ(I), IA(I), IKEY(I), DEN(I).  
(See Section 2.3.2, card type 24.)

Cards of the types 21 through 26 must be supplied as appropriate for each region.

Cards 1 through 26 are supplied as appropriate for each case desired.

Termination of the NAP calculation is made by a card with the word LAST starting in column 1 of the card at the end of all data.

### 3.3.3 Output Description

NAP program output is largely self-explanatory. If region-dependent neutron group fluxes are input to the problem, the group fluxes will appear in the output in order of increasing region number, but the regions are not identified on the flux output. In many cases, two or more atom densities will be printed for the same radioisotope. This will occur whenever the radioisotope is produced in more than one manner. Atom densities, gamma ray source strengths, energy source strengths, dose rates, and doses are printed as a function of time, region by region.

For the INAP system, all the output to be passed to the FASTER program is also printed out as card images in the format suitable for the INAP FASTER program. The variables which are passed on to FASTER are given in Figure 3.4-1.

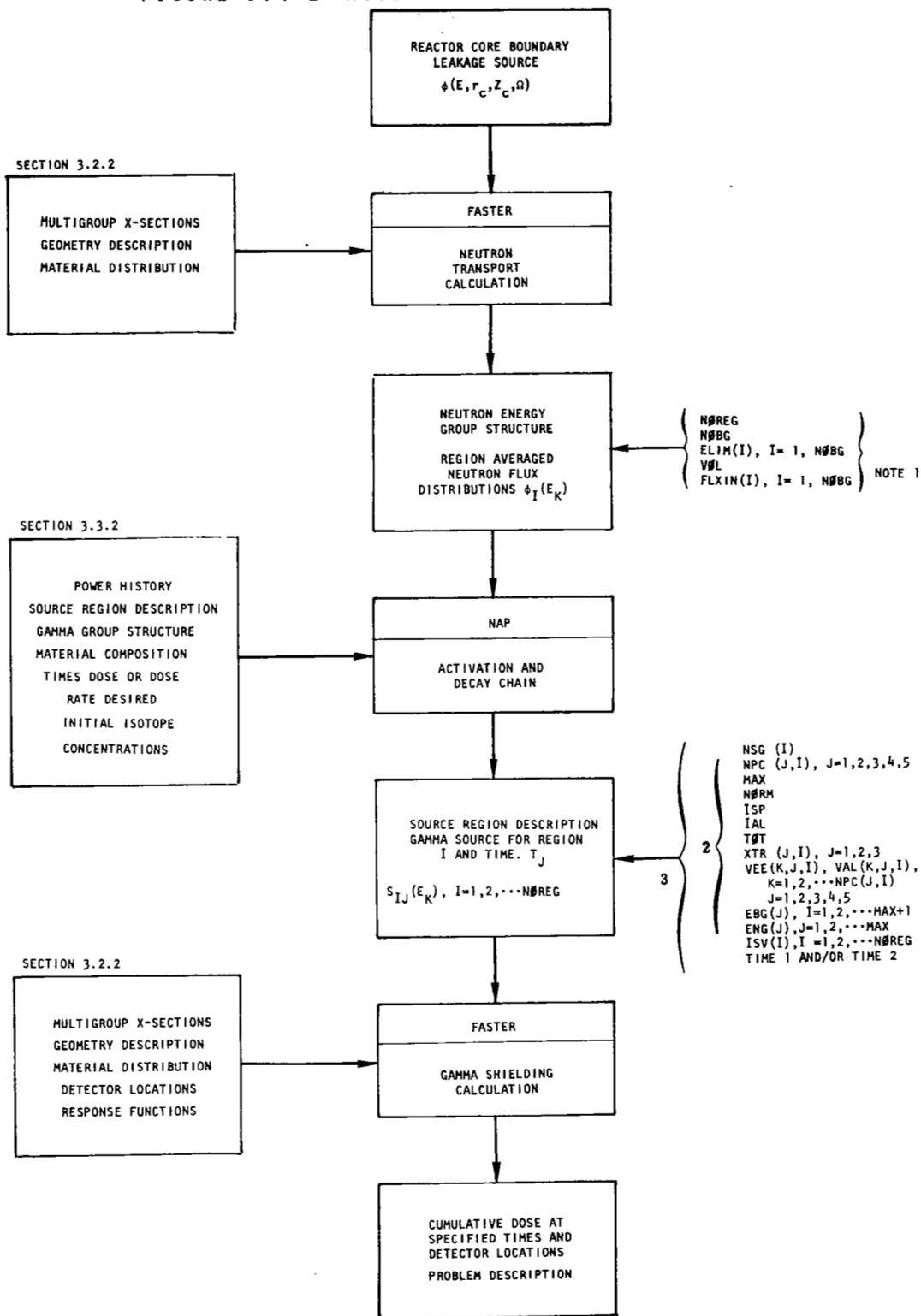
### 3.4 System Operation

The programs of the INAP Accurate System are executed in succession with input data as shown in Figure 3.4-1. The data transferred from any one program module to the following module are all contained on punched cards which are placed with the input data prepared by the user. Figure 3.4-1 identifies those variables transferred between modules. The input routines of the programs have been changed so that the user is never required to insert cards or collate input decks.

The neutron transport module, FASTER, is executed first to determine the space dependent neutron flux in those regions being activated. These regions, of course, become the source regions for the gamma ray shielding module. As FASTER is used for both the neutron transport and gamma ray shielding calculations, much of the input, particularly the geometry description, need be prepared only once and input to both calculations, thereby reducing considerably the data preparation required. In addition, NAP input routines have been modified to accept those variables which, along with the neutron flux intensity output by the neutron calculations, complete the description of the gamma source. These variables, listed in Figure 3.4-1 and described in Section 3.2.2, are output by NAP with the gamma source for input to FASTER for the appropriate number of times or time intervals. Each time or time interval is treated by FASTER as a separate case, with the exception that the result of the dose calculations are accumulated and printed as output after each time interval. For the gamma ray shielding calculation the user prepares only one set of input data regardless of the number of times considered.

To exercise the Accurate System, the user must prepare all the input to FASTER for the neutron calculations. The punched cards prepared by FASTER are then placed behind a header card prepared by the user and this deck is placed before the remaining part of the NAP input data deck. NAP will prepare a deck of punched cards which is then placed behind the FASTER input data deck prepared by the user for the gamma ray shielding calculations.

FIGURE 3.4-1 ACCURATE CODE SYSTEM FLOW CHART



NOTES:

1. DATA REPEATED FOR EACH ACTIVATED REGION. THE TOTAL NUMBER OF ACTIVATED REGIONS EQUALS NOREG.
2. REPEATED FOR EACH SOURCE REGION.
3. REPEATED AS REQUIRED FOR EACH TIME AT WHICH DOSE OR DOSE RATE CALCULATION IS DESIRED.

### 3.5 Accurate System Sample Problem

This section briefly describes a sample problem for the INAP Accurate System and gives card images of the input required by each component program. To conserve space only the output relevant to the INAP System which is sufficient to verify the system operation is shown. Card inputs prepared by a component code and not by the user are enclosed in boxes for identification.

The sample problem for the Accurate System is similar to that for the Engineering System. It consists of a simplified reactor section and a section of a fuel storage tank shown in Figures 3.5-1 and 3.5-2. The FASTER neutron calculation utilizes 3 energy groups (see Table 2.6-1) and one source volume (region I) consisting of nine material regions containing five materials. The region locations can be seen on Figure 3.5-1 and the compositions are given in Table 2.6-2. The surface locations and types are given in Table 3.5-1. All the input to the FASTER neutron calculation, shown on pages 167 to 169 must be prepared by the user. The punched card output to be used by NAP is found on page 170. Unlike the Engineering System, no header card is punched by the neutron transport module. Hence, the user must prepare a header card for the NAP input.

Again the NAP calculation considers only those regions, I, III, V, VI, and VIII and materials Fe,  $U^{235}$ ,  $U^{238}$  and Al, which yield a significant activation gamma source. The source power history is a one hour square pulse and the decay chain calculations are carried to 1000 hours. Two times were chosen for a dose calculation by FASTER, that is, at 7.5 hours and 650 hours. The gamma energy group structure used by NAP and FASTER is given in Table 2.6-1. The card images of the input for NAP are shown on pages 170 to 172.

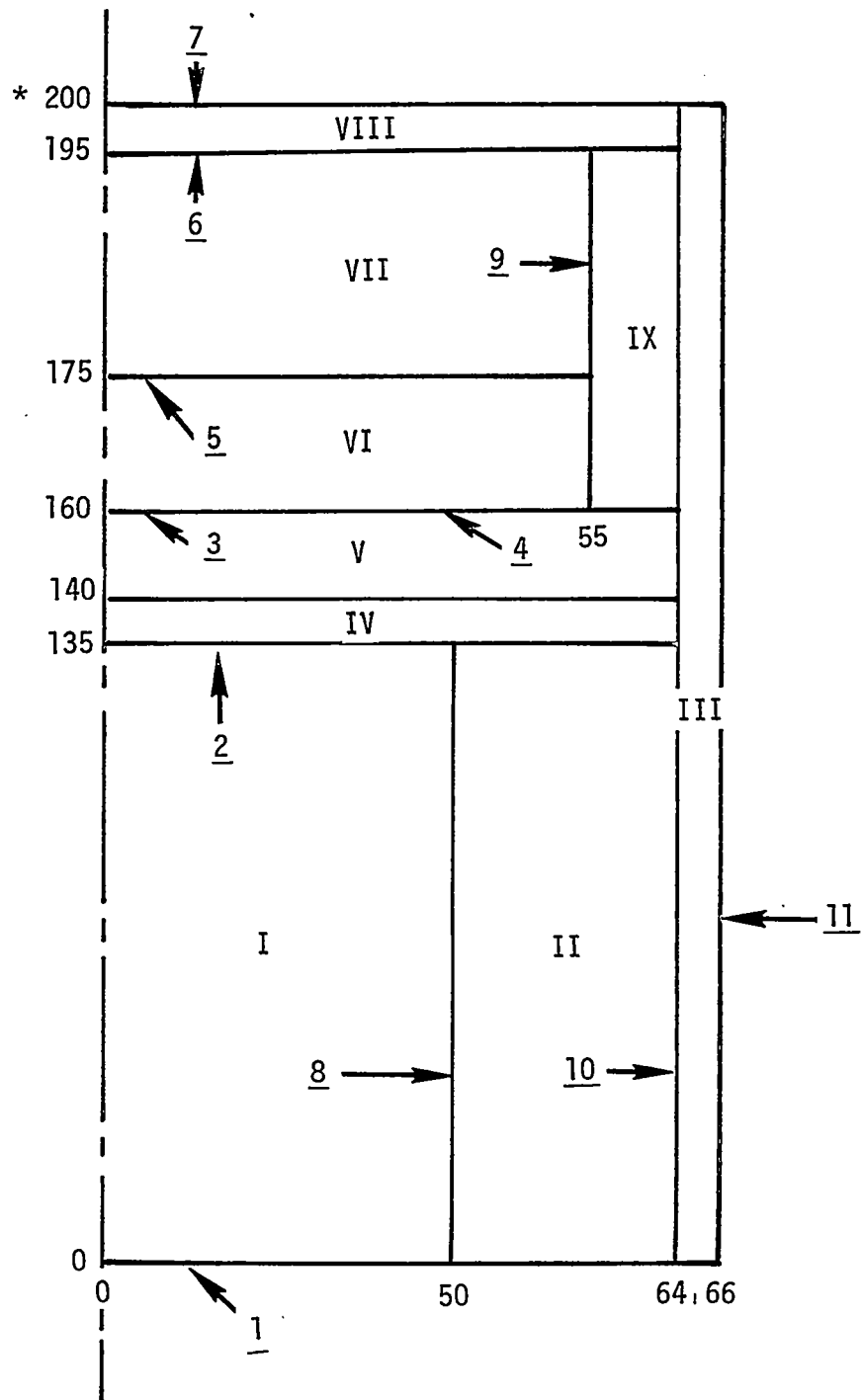
The FASTER gamma ray shielding calculation consists of 15 regions (see Figures 2.6-1 and 3.5-2) and three detectors. The compositions of the regions are given in Table 2.6-3 and the boundary surface locations and types are given in Table 2.6-4. The card images of the input data for the FASTER gamma ray shielding calculation are shown on pages 173 to 177. A sample of the time dependent print out is given on page 178 for detector three at 650 hours.

Listing the entire output of each code in the system is extensive, therefore, only the most relevant output information is provided in this report. All program listings, as well as sample problem input and output have been placed on magnetic tape.

TABLE 3.5-1 Surface Locations for FASTER  
Neutron Calculations

Surface Index	Type	Location
1	plane at	Z = 0 cm
2	"	135
3	"	140
4	"	160
5	"	175
6	"	195
7	"	200
8	cylinder radius	= 50
9	"	55
10	"	64
11	"	66

\* DIMENSIONS IN CENTIMETERS



NOTE: REGIONS ARE IDENTIFIED BY ROMAN NUMERALS AND SURFACES BY ARABIC NUMBERS UNDERLINED.

FIGURE 3.5-1 GEOMETRY OF CORE REGION FOR SAMPLE PROBLEM

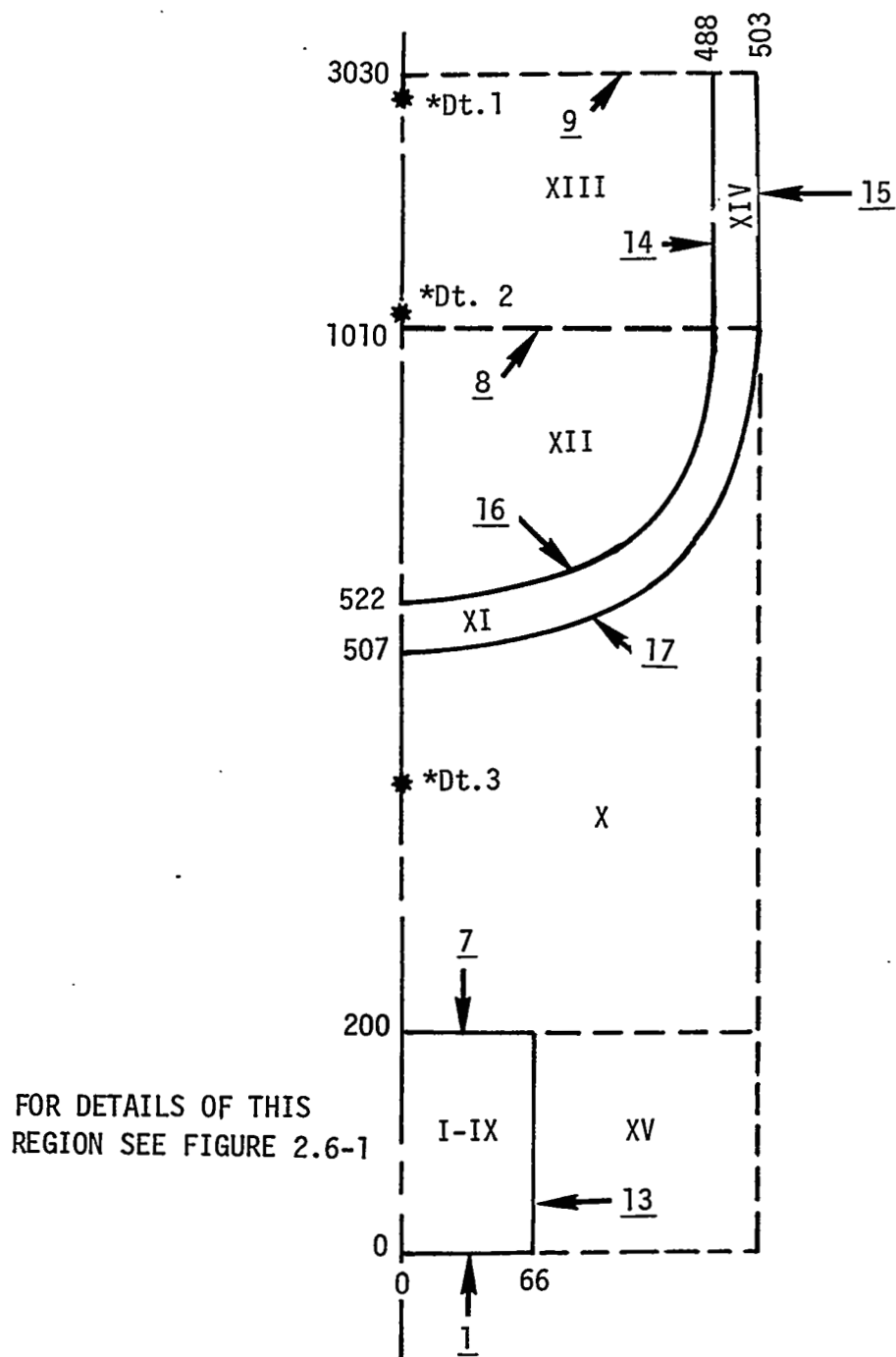


FIGURE 3.5-2 GAMMA RAY SHIELDING GEOMETRY FOR ACCURATE SYSTEM SAMPLE PROBLEM

0 1 1 1 1 1 1 1 1 1 1  
INAP SAMPLE PROBLEM ACCURATE SYSTEM  
NEUTRON PART

[illegible]

12.01	6.0	1.504	1.656	0.0	0.0	0.0	3-4-2
1.96348	4.81587	4.89378					3-5-2
1 2 0 0 0 0							3-6-2
1.69738	4.74768	4.89204					3-7-2
0.240239	0.0680873						3-8-2
26.98	13.0	0.0	0.0	2.7	0.0	2.24	3-4-3
2.72232	2.38250	1.66828					3-5-3
1 2 0 0 0 0							3-6-3
2.49071	2.33776	1.54753					3-7-3
0.183629	0.0337385						3-8-3
55.85	26.0	1.143 E-2	0.0	0.0	2.0	0.0	3-4-4
3.17087	9.06424	12.0795					3-5-4
1 2 0 0 0 0							3-6-4
2.95819	8.94156	10.7916					3-7-4
0.191227	0.0264936						3-8-4
235.15	92.0	7.31 E-2	0.0	0.0	0.0	0.0	3-4-5
7.13804	48.8674	345.243					3-5-5
1 2 0 0 0 0							3-6-5
4.94237	11.0413	14.0					3-7-5
0.776368	8.0345E-3						3-8-5
0 0 2 5 0 0							4-0
1 0 TOTAL N	1.0	1.0	1.0	1.0	1.0		4-3-1
2 1 TOTAL E	1.0	1.0	1.0	1.0	1.0		4-3-2
1 1 01060287.5	0.0	0.0	0.0	0.0	0.0		4-4-1
2 3 0163362.82	0.0	0.0	0.0	0.0	0.0		4-4-2
3 5 0257359.27	0.0	0.0	0.0	0.0	0.0		4-4-3
4 6 0142549.77	0.0	0.0	0.0	0.0	0.0		4-4-4
5 8 0 64339.82	0.0	0.0	0.0	0.0	0.0		4-4-5
0 1 0 1 0 0 1 1 1							5-0
1.0 E+10	0.0	0.0	0.0	5.0 E+10	0.0	0.0	5-2
1.0	1.0	1.0	1.0	0.0			5-4-1
1.0	1.0	1.0	1.0	1.0			5-4-2
10.0	10.0	10.0					5-7
1000.0	1000.0	1000.0					5-8
1.0	1.0	1.0	1.0	E-4 1.0	0.9	1.0	5-9
0 1 1 0 0 0 0 1							6-0

1	1	2	2	2	2	2	3	0	2	2	6361725.2	0.0	0.0	0.0	6-2
0.0		1.0			50.0				1.0						6-3-1
-3.1416		1.0			3.1416				1.0						6-3-2
0.0		1.0			135.0				1.0						6-3-3
-3.1416		1.0			3.1416				1.0						6-3-4
-1.0		1.0			1.0				1.0						6-3-5
14.9182		0.550232			4.14	E-7		1.0	E-9						6-4-1
1.0		2.0			3.0										6-4-2
				5											6-0

# NAP SAMPLE PROBLEM FOR INAP SYSTEM FASTER-VERSION

```

      5      3
1.49182E+01 5.50232E-01 4.14000E-07 1.00000E-09
1.06029E+06
2.36953E+01 7.61568E+01 4.85566E+01
1.63363E+05
2.22919E-01 3.72933E-02 4.37024E-02
2.57359E+05
3.33931E-01 8.31087E-03 5.98414E-03
1.42550E+05
2.04347E-02 1.05941E-08 6.96150E-10
6.43398E+04
1.71731E-04 6.72656E-17 9.12513E-19

```

```

      0
      1
      5
10.0      4.0      1.0      0.4      0.2      0.001
1.0      0
      5      0
4.0      0.0      0.0      0.0      0.0
1.0      1.0      8.0      90.0      900.0
      1      5      8      9      9
      -2
7.5      650.0
      0
      0      1
      1      2      2      2      2
0.0      0.0      0.0
0.0      1.0      50.0      1.0
-3.1416      1.0      3.1416      1.0
0.0      1.0      135.0      1.0
-3.1416      1.0      3.1416      1.0

```

-1.0		1.0		1.0		1.0	
	3	68.5		0.0			
26 58	1	3.9172	E-7	92235	1	1.78015 E-4	92238 1 9.2512 E-6
1	2	2	2	2	2		
0.0		0.0		0.0			
64.0		1.0		66.0		1.0	
-3.1416		1.0		3.1416		1.0	
0.0		1.0		200.0		1.0	
-3.1416		1.0		3.1416		1.0	
-1.0		1.0		1.0		1.0	
	1	68.5		0.0			
13 27	1	6.024	E-2				
1	2	2	2	2	2		
0.0		0.0		0.0			
0.0		1.0		64.0		1.0	
-3.1416		1.0		3.1416		1.0	
140.0		1.0		160.0		1.0	
-3.1416		1.0		3.1416		1.0	
-1.0		1.0		1.0		1.0	
	1	68.5		0.0			
26 58	1	6.855	E-5				
1	2	2	2	2	2		
0.0		0.0		0.0			
0.0		1.0		55.0		1.0	
-3.1416		1.0		3.1416		1.0	
160.0		1.0		175.0		1.0	
-3.1416		1.0		3.1416		1.0	
-1.0		1.0		1.0		1.0	
	1	68.5		0.0			
13 27	1	5.0	E-2				
1	2	2	2	2	2		
0.0		0.0		0.0			
0.0		1.0		64.0		1.0	
-3.1416		1.0		3.1416		1.0	
195.0		1.0		200.0		1.0	
-3.1416		1.0		3.1416		1.0	

-1.0	1.0	1.0	1.0
	1 68.5	0.0	
13 27	1 6.024	E-2	
LAST			

0 1 1 1 1 1 0 1 1 1 1  
 INAP SAMPLE PROBLEM ACCURATE SYSTEM  
 GAMMA PART

17 6 15 4 26

5 5 2 10

0 1 0 5 5

5 2 0 0 1 0 3 0

1 0 1 0 1

4 25 5 20

0 17 15 1 1

1 3 3 0.0

2 3 3 135.0

3 3 3 140.0

4 3 3 160.0

5 3 3 175.0

6 3 3 195.0

7 3 3 200.0

8 3 3 1010.0

9 3 3 3030.0

10 5 12 0.0 50.0 0.0 50.0

11 5 12 0.0 55.0 0.0 55.0

12 5 12 0.0 64.0 0.0 64.0

13 5 12 0.0 66.0 0.0 66.0

14 5 12 0.0 488.0 0.0 488.0

15 5 12 0.0 503.0 0.0 503.0

16 6 13 0.0 488.0 0.0 488.0 1010.0 488.0

17 6 13 0.0 503.0 0.0 503.0 1010.0 503.0

1 0 1 1 2 10

2 0 2 1 2 10 12

3 0 3 1 7 12 13

4 0 0 2 3 12

5 0 4 3 4 12

6 0 5 4 5 11

7 0 0 5 6 11

8 0 3 6 7 12

9 0 0 4 6 11 12

5.36 E-4 1.0 1.0 1.0

1.4 E-3 51.0 0.0 1.0

0.0 65.0 0.0 1.0

7.0 E-2 1.0 1.0 136.0

4.73 E-2 1.0 1.0 141.0

1.26 E-2 1.0 1.0 161.0

7.0 E-2 1.0 1.0 176.0

0.0 1.0 1.0 196.0

7.0 E-2 56.0 0.0 161.0

1-0

1-2

1-3

1-4

1-5

1-6

1-8

1-9

1-10

2-0

2-2-1

2-2-2

2-2-3

2-2-4

2-2-5

2-2-6

2-2-7

2-2-8

2-2-9

2-2-10

2-2-11

2-2-12

2-2-13

2-2-14

2-2-15

2-2-16

2-2-17

2-3-1

2-3-2

2-3-3

2-3-4

2-3-5

2-3-6

2-3-7

2-3-8

2-3-9

10	0	-1	7	8	15	17	0.0	1.0	1.0	201.0	2-3-10
11	0	3	8	16	17		0.0	1.0	1.0	508.0	2-3-11
12	0	0	8	16			7.0	E-2 1.0	1.0	523.0	2-3-12
13	0	0	8	9	14		7.0	E-2 1.0	1.0	1011.0	2-3-13
14	0	3	8	9	14	15	0.0	489.0	0.0	1011.0	2-3-14
15	0	-1	1	7	13	15	0.0	67.0	0.0	1.0	2-3-15
0	0	1	0	0	1	1					3-0
10.0	4.0		1.0	0.4	0.2	0.001					3-2
1.008	1.0		0.0	0.0	0.0	0.0	0.0	0.0			3-4-1
5.431	E-29.695	E-22.112	E-13.166	E-14.064	E-11.224	E+1					3-5-1
12.01	6.0	1.504	1.656	0.0	0.0	0.0					3-4-2
.3899	.6055	1.268	1.903	2.451	4.299	E+4					3-5-2
26.98	13.0	0.0	0.0	2.7	0.0	2.24					3-4-3
1.036	1.384	2.751	4.161	5.507	5.143	E+4					3-5-3
55.85	26.0	.01143	0.0	0.0	2.0	0.0					3-4-4
2.769	3.04	5.533	8.662	13.43	8.505	E+5					3-5-4
235.15	92.0	.0731	0.0	0.0	0.0	0.0					3-4-5
20.11	17.02	30.78	112.7	501.5	2.95	E+6					3-5-5
0	0	2	3	0	0						4-0
1	0	TOTAL N	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	4-3-1-1
1.0											4-3-1-2
2	1	TOTAL E	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	4-3-2-1
1.0											4-3-2-2
1	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3028.0	4-4-1
2	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1011.0	4-4-2
3	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	400.0	4-4-3
0	1	1	1	0	0	0	0	1			5-0
1.0	E+10	0.0	0.0	5.0	1.0	E+10	0.0	0.0	10.0		5-2
1.0	1.0	1.0	1.0	1.0	1.0						5-3
1.0	1.0	1.0	1.0	1.0	0.0						5-4-1-1
1.0	1.0	1.0	1.0	1.0	1.0						5-4-1-2
65.0	1.0	1.0	1.0	1.0	0.0						5-4-2-1
1.0	1.0	1.0	1.0	1.0	1.0						5-4-2-2
1.0	1.0	141.0	1.0	0.0							5-4-3-1
1.0	1.0	1.0	1.0	1.0							5-4-3-2
1.0	1.0	161.0	1.0	0.0							5-4-4-1

1.0	1.0	1.0	1.0	1.0				5-4-4-2
1.0	1.0	196.0	1.0	0.0				5-4-5-1
1.0	1.0	1.0	1.0	1.0				5-4-5-2
1.0	1.0	1.0	1.0	E-4 1.0	0.9	1.0		5-9

0	1	5	0	0	2	1	1						
1	1	2	2	2	2	2	5	0	2	2	1060E+03	0	0
0			1000E-03	5000E-02	1000E-03								
-3142E-03			1000E-03	3142E-03	1000E-03								
0			1000E-03	1350E-01	1000E-03								
-3142E-03			1000E-03	3142E-03	1000E-03								
-1000E-03			1000E-03	1000E-03	1000E-03								
1000E-02			4000E-03	1000E-03	4000E-04	2000E-04	1000E-06						
0			3601E-10	2244E-10	4323E-07	2783E-05							
2	1	2	2	2	2	2	5	0	2	2	1634E+02	0	0
6400E-02			1000E-03	6600E-02	1000E-03								
-3142E-03			1000E-03	3142E-03	1000E-03								
0			1000E-03	2000E-01	1000E-03								
-3142E-03			1000E-03	3142E-03	1000E-03								
-1000E-03			1000E-03	1000E-03	1000E-03								
1000E-02			4000E-03	1000E-03	4000E-04	2000E-04	1000E-06						
0			1681E-06	3106E-07	0	3106E-09							
3	1	2	2	2	2	2	5	0	2	2	2574E+02	0	0
0			1000E-03	6400E-02	1000E-03								
-3142E-03			1000E-03	3142E-03	1000E-03								
1400E-01			1000E-03	1600E-01	1000E-03								
-3142E-03			1000E-03	3142E-03	1000E-03								
-1000E-03			1000E-03	1000E-03	1000E-03								
1000E-02			4000E-03	1000E-03	4000E-04	2000E-04	1000E-06						
0			7374E-12	0	0	2212E-13							
4	1	2	2	2	2	2	5	0	2	2	1425E+02	0	0
0			1000E-03	5500E-02	1000E-03								
-3142E-03			1000E-03	3142E-03	1000E-03								
1600E-01			1000E-03	1750E-01	1000E-03								
-3142E-03			1000E-03	3142E-03	1000E-03								

-1000E-03	1000E-03	1000E-03	1000E-03						
1000E-02	4000E-03	1000E-03	4000E-04	2000E-04	1000E-06				
0	1509E-08	2325E-08	0	2325E-10					
5	1	2	2	2	2	2	5	0	2
0									
	1000E-03	6400E-02	1000E-03						
-3142E-03	1000E-03	3142E-03	1000E-03						
1950E-01	1000E-03	2000E-01	1000E-03						
-3142E-03	1000E-03	3142E-03	1000E-03						
-1000E-03	1000E-03	1000E-03	1000E-03						
1000E-02	4000E-03	1000E-03	4000E-04	2000E-04	1000E-06				
0	1528E-10	2354E-10	0	2354E-12					
0	7500E-03								
0	1	5	0	0	2	0	0		
1	1	2	2	2	2	2	5	0	2
0									
	1000E-03	5000E-02	1000E-03						
-3142E-03	1000E-03	3142E-03	1000E-03						
0	1000E-03	1350E-01	1000E-03						
-3142E-03	1000E-03	3142E-03	1000E-03						
-1000E-03	1000E-03	1000E-03	1000E-03						
1000E-02	4000E-03	1000E-03	4000E-04	2000E-04	1000E-06				
0	2705E-08	6977E-09	5458E-06	2720E-05					
2	1	2	2	2	2	2	5	0	2
6400E-02	1000E-03	6600E-02	1000E-03						
-3142E-03	1000E-03	3142E-03	1000E-03						
0	1000E-03	2000E-01	1000E-03						
-3142E-03	1000E-03	3142E-03	1000E-03						
-1000E-03	1000E-03	1000E-03	1000E-03						
1000E-02	4000E-03	1000E-03	4000E-04	2000E-04	1000E-06				
0	1829E-07	1676E-19	0	1676E-21					
3	1	2	2	2	2	2	5	0	2
0									
	1000E-03	6400E-02	1000E-03						
-3142E-03	1000E-03	3142E-03	1000E-03						
1400E-01	1000E-03	1600E-01	1000E-03						
-3142E-03	1000E-03	3142E-03	1000E-03						
-1000E-03	1000E-03	1000E-03	1000E-03						
1000E-02	4000E-03	1000E-03	4000E-04	2000E-04	1000E-06				

0	5538E-10	0	0	1662E-11			
4 1 2 2 2 2 5 0 2 2				1425E+02	0	0	0
0	1000E-03	5500E-02	1000E-03				
-3142E-03	1000E-03	3142E-03	1000E-03				
1600E-01	1000E-03	1750E-01	1000E-03				
-3142E-03	1000E-03	3142E-03	1000E-03				
-1000E-03	1000E-03	1000E-03	1000E-03				
1000E-02	4000E-03	1000E-03	4000E-04	2000E-04	1000E-06		
0	1369E-08	1255E-20	0	1255E-22			
5 1 2 2 2 2 5 0 2 2				6434E+01	0	0	0
0	1000E-03	6400E-02	1000E-03				
-3142E-03	1000E-03	3142E-03	1000E-03				
1950E-01	1000E-03	2000E-01	1000E-03				
-3142E-03	1000E-03	3142E-03	1000E-03				
-1000E-03	1000E-03	1000E-03	1000E-03				
1000E-02	4000E-03	1000E-03	4000E-04	2000E-04	1000E-06		
0	1387E-10	1270E-22	0	1270E-24			
7500E-03	6500E-01						

INAP SAMPLE PROBLEM ACCURATE SYSTEM  
GAMMA PART

\*\*\*\*\*THE FASTER CODE\*\*\*\*\*CASE 1  
\*\*\*\*\*T.M. JORDAN, WANL\*\*\*\*\*PAGE 38

\*\*\*\*\* CUMULATIVE TIME RESULTS FOR DETECTOR 3 AFTER 6.50000E+02 HRS\*\*\*\*\*

	FLUX	RESP 1	RESP 2
GROUP 1..	0.	0.	0.
GROUP 2..	2.9132E-01	2.9132E-01	7.0169E-01
GROUP 3..	1.9562E-01	1.9562E-01	1.1974E-01
GROUP 4..	1.4251E-01	1.4251E-01	3.9174E-02
GROUP 5..	3.2009E-09	3.2009E-09	6.3918E-10
TOTALS.....	6.2944E-01	6.2944E-01	8.6060E-01

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